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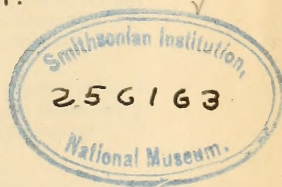
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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*The Worship of Meteorites*; by HUBERT A. NEWTON.

[A lecture delivered* in New Haven, Conn., March 29, 1889.]

HERE is a small fragment of iron that has a curious history. It is a portion of a mass of meteoric iron found upon a brick altar in one of the Ohio mounds. Along with it were various objects—a serpent cut out of mica—several terracotta figurines—two remarkable dishes carved from stone into the form of animals; pearls, shells, copper ornaments, and nearly three hundred ankle bones of deer and elk. There were but one or two fragments of other bones, and one animal furnished but two of these ankle bones; hence they must have been selected for some special, important reason. The figurines had been apparently broken for some purpose, and the whole collection had suffered in the fire not a little. In a like altar of another mound of the same group were found nearly two bushels of like objects.

It must have been in some ceremony of a religious, possibly one of a funereal, character that the mound builders collected here on the altar their ornaments and other valuables, and after burning them buried the charred debris in the huge earthen mound that was built over them and the altar.

* This lecture has not hitherto been published; perhaps the author regarded it as hardly falling within the sphere of a scientific journal. Even if this be the case, however, the general interest of the subject is such as to justify its being printed now. Further, it seems due to the author that the scientific public should have the benefit of all his contributions to the subject to which he gave so much study. It may be added that the biographical notice of Professor Newton, it is expected, will appear in the May number.—EDITORS.

AM. JOUR. SCI.—FOURTH SERIES, VOL. III, NO. 13.—JANUARY, 1897.

What would we not give if this fragment could be endowed with the power of repeating to us its experience,—chapters in the history of that people? But nearly all that we can say is that it was found among objects held by them in peculiar esteem, and used by them in some serious, probably religious ceremony.

There was formerly, and so far as I know there is still, in the collection of meteorites in Munich, a stone that weighs about a pound. It fell in 1853 in the region north of Zanzibar on the East African coast, and was seen and picked up by some shepherd boys. The German missionaries tried to buy it, but the neighboring Wanikas, because it fell from heaven, took it to be a god. They secured possession of it, anointed it with oil, clothed it with apparel, ornamented it with pearls, and built for it a kind of temple to give it proper divine honors. The agents of the missionaries were not allowed even to see the stone, far less could they purchase the Wanika's tutelary deity. Neither entreaties, nor arguments, nor offers of the missionaries, nor of the officials were of any avail. But when three years later the wild nomad tribes of the Masai came down upon the Wanikas, burned their village, and killed large numbers of them, the Wanikas thought very differently of the stone's protecting power. In fact they lost all respect for it. A famine having meanwhile arisen, the elders of the tribe were quite ready to exchange their palladium for the silver dollars of the missionaries.

Among the Buddha legends is one of two merchants who offered food to the Buddha, which was accepted, and in consequence of their request for some memorial of him the Buddha gave them a hair and fragments of his nails, and told them that hereafter a stone should fall from heaven near the place where they lived, and that they should erect a pagoda and worship these relics as though they were Buddha himself.

The nations of India have always been specially superstitious about stones fallen from the skies. In 1620 an aerolite fell near Jullunder, and the king sent for a man well known for the excellent sword blades that he made, and ordered him to work the lump into a sword, a dagger and a knife. The mass, however, would not stand the hammer, but crumbled in pieces. By mixture with iron of the earth the required weapons were made.

In 1867 a shower of stones fell, some forty in number, at Saonlod. The terrified inhabitants of the village, seeing in them the instruments of vengeance of an offended deity, set about gathering all they could find, and having pounded them into pieces they scattered them to the winds.

In 1870 a meteorite fell at Nidigullam, and the Hindoos at

once carried it to their temple and worshiped it. The same has been repeated in India on the occasion of several other stonefalls in the present century. One native ruler refused to allow a stone to be carried across his territory for fear of the injury that might come to his people or his lands.

Two Japanese meteorites, formerly the property of a daimio family, were long kept and handed down as heirlooms, being in the care of the priests in one of the family temples. They were among the family offerings made to Skokujo on her festival days. They were connected with her worship by the belief that they had fallen from the shores of the Silver River, Heavenly River, or Milky Way, after they had been used by her as weights with which to steady her loom. One of these stones was presented by its late owner to the British Museum, and it is in its collection of meteorites.

There is a curious institution among the Chinese that has existed, according to Biot, from a time more than one thousand years before Christ. The Chinese attributed to different groups of stars a direct influence upon different parts of the empire. Some of these groups correspond, for example, to the imperial palaces, to the rivers, the roads, and the mountains of China. By reason of this belief regular observations are made by the imperial astronomers of all that passes in the heavens, especially of the groups of stars in which comets and meteors originate, or across which they travel. The interpretation of what is seen in the sky forms part of the duties of these very important officials. These observations have been carefully written out, and are preserved in the archives of the empire. Upon the ending of a dynasty, by change of name or otherwise, these comet and meteor records have been published as a special chapter of the chronicles of the dynasty. The existing dynasty began in 1647, since which date the records are, therefore, unpublished.

In 1492 a stone of 300 pounds weight fell at Ensisheim, in Alsace. The Emperor Maximilian, then at Basel, had the stone brought to the neighboring castle, and a Council of State was held to consider what message from heaven the stonefall brought to them. As a result the stone was hung up in the church with an appropriate legend and with strictest command that it should ever remain there intact. It was held to be an omen of import in the contest then in progress with France and in the contest impending with the Turks. Nineteen years later a shower of stones fell near Crema, east of Milan. The pope was at war with the French and the stones fell into the French territory. Before the year had passed the French, after a long possession of Lombardy and serious threatening of the States of the Church, were forced to retire from Italy. At

this time Raphael was painting for an altar-piece his magnificent Madonna di Foligno now in the Vatican. Beneath the rainbow in the picture, indicating Divine reconciliation, Raphael painted also this Crema fireball apparently to set forth Divine aid and deliverance.

I have thus rapidly gone over some selected facts showing how the mound-builders, the wild Africans, the Hindoos, the Japanese, the Chinese, the modern Europeans have been ready to revere these myfterious bodies that come from the skies. But it is in the Greek and Latin literature that we have reason to expect the more numerous and full accounts, both legendary and historic, of this reverence and worship.

It is now I believe admitted by the best scholars that both in Greece and in Italy, there was a period earlier than the age of images, when the objects worshiped were not wrought by hand. Men worshiped trees and caves, groves and mountains and also unwrought stones. Even after men began to make their objects of worship, these were in many cases mere hewn stones, not images. The earlier Greek term *ἄγαλμα*, an object of worship, stands apart from the later term *εἰκόν*, image.

What would be more natural in that age to the affrighted witnesses of the most magnificent of spectacles, the fall of a meteorite, than for them to regard the object which had come out of a clear sky, with terrific noise and fire and smoke, as something sent to them by the gods to be revered and worshiped? It was nobler to worship a stone fallen from the sky than one of earthly origin.

The worship of an unwrought stone once established has wonderful vitality. For example, the Greek writers speak of such a worship in their day among the Arabian tribes. When Mohammed with his intense iconoclasm came down upon Mecca and took the sacred city, he either for reasons of policy, or from feeling, spared the ancient worship of this black stone. Entering into the sacred inclosure he approached and saluted it with his staff (where it was built into the corner of the Kaaba), made the sevenfold circuit of the temple court, returned and kissed the stone, and then entered the building and destroyed the 360 idols within it. To-day that stone is the most sacred jewel of Islam. Toward it each devout Moslem is bidden to look five times a day as he prays. It is called the Right Hand of God on Earth. It is reputed to have been a stone of Paradise, to have dropped from heaven together with Adam. Or, again, it was given by Gabriel to Abraham to attest his divinity. Or, again, when Abraham was reconstructing the Kaaba that had been destroyed by the deluge, he sent his son Ishmael for a stone to put in its corner, and Gabriel met Ishmael and gave him this stone. It was originally transparent hyacinth, but

became black by reason of being kissed by a sinner. In the day of judgment it will witness in favor of all those who have touched it with sincere hearts, and will be endowed with sight and speech. The color of this stone, according to Burekhardt, is deep reddish brown, approaching to black; it is like basalt, and is supposed by some to be a meteorite.

It is not important for my purpose to separate the history from the myth. Eusebius quotes from an old Phœnician writer, Sanchouniathon, that the Goddess Astarte found a stone that fell from the air, that she took it to Tyre, and that they worshiped it there in the sacred shrine. We have reason to question whether that Phœnician writer ever lived. What matters it? The existence of the story in Eusebius' time has to us a significance not greatly unlike that of the existence of the worship itself in the earlier years.

Vergil describes a detonating meteor in such terms that I feel reasonably sure that either he had seen and heard, or else he had had direct conversations with others who had seen and heard, a splendid example of these meteors. The passage is in the second book of the *Aeneid*. The city of Troy was captured and was burning. All was in confusion. The family of Aeneas was gathered ready for flight, but Anchises would not go. An omen, lambent flames on the head of his grandson, began only to shake his purpose to perish with his country. He prayed for more positive guidance. It is Aeneas who describes the scene :

"Hardly had the old man spoken when across the darkness a star ran down from the sky carrying a brilliant light torch. We saw it go sweeping along above the roof of the house. It lighted up the streets and disappeared in the woods on Mount Ida. A long train, a line of light, remained across the sky, and all around the place was a sulphurous smell. A heavy sound of thunder came from the left. Overcome now, my father raised his hands to heaven, addressed the gods and worshiped the sacred star. Now, now, he cried, no longer delay."

This story is, of course, all legendary, but Vergil's description of the scene is true to life as conceived by pagan Rome in his day.

The images that fell down from Jupiter, or that fell from the skies, are often spoken of by Greek and by Latin writers. I mention three or four cases only where this allusion points to a meteoric origin as possible or probable. The earliest representative of Venus at old Paphos on the island of Cyprus, was one of these heaven-descended images. It was not the Venus of the Capitol, nor the Venus of Milo, but as described was a rude triangular stone.

Cicero, in the grand closing passage of his oration against

Verres, calls upon Ceres, whose statue he says was not made by hands but was believed to have fallen from the skies. The earliest of the images of Pallas at Athens was said to have had a like origin. Pausanias saw at Delphi a stone of moderate size which they anointed every day, and covered during every festival with new shorn wool. They are of opinion, he adds respecting this stone, that it was the one given by Cybele to Saturn to swallow as a substitute for the infant Jupiter, which Saturn after swallowing vomited out on the earth.

There is a marvelous story of a peculiar stone in the poem *Lithika* by the apocryphal Orpheus. Phoebus Apollo gave the stone to the Trojan Helenus, and Helenus used it in soothsaying. It was called Orites, and by some *Siderites*. It had the faculty of speech, and when Helenus wished to consult it he performed special ablutions and fasts for twenty-one days, then made various sacrifices, bathed the stone in a living fountain, dressed it and carried it in his bosom. The stone now became alive, and to make it speak he would take it in his arms and dandle it, when the stone would begin to cry like a child for the breast. Helenus would now question the stone, and receive its answers. By means of these he was able to foretell the ruin of the Trojan state. Whoever framed that story had, I believe, before him a real stone, and the description is very like that of a meteorite, saying nothing of its having come from Apollo. The Orphic writer says that it was rough, rounded, heavy, black, and close-grained. Fibers like wrinkles were drawn in circular forms over the whole surface above and below.

Here I show you a stone such as was described—rounded, black, heavy, close-grained, and having fibers like wrinkles in circular forms over the whole surface above and below.

The name *Siderites* was at a later date applied to the load-stone, but by this writer the two stones are separately described, and are apparently distinct. If this name was of Greek origin it seems to be allied to *sideros*, *iron*, and this heavy stone, like nearly all meteorites, probably contained iron. If, however, this name came from a Latin source (for it is used both by Greek and by Latin writers) it has affinities with *Sidus*, a star, and its meteoric character is still more clearly indicated.

One of the most interesting of the stories about images that have fallen from heaven, is the basis of that beautiful tragedy of Euripides, "*Iphigeneia in Tauris*." To many of you the story is familiar, but it will bear repetition.

The goddess Diana detained at Aulis the Grecian fleets by contrary winds, and required the sacrifice of Iphigeneia, the daughter of Agamemnon, before the Greeks could set sail. The father consented;—and the daughter, apparently sacri-

ficed, was really rescued by Diana, and borne to the Tauric, or Crimean peninsula on the north shore of the Black Sea. She was then made a priestess in the temple of the goddess. At this shrine the barbaric inhabitants used to sacrifice before an image of Diana, that fell from heaven, all strangers that were shipwrecked upon the coast. The unhappy Iphigeneia, forced to take a leading part in these human sacrifices, laments her sad lot:—

“ But now a stranger on this strand,
 'Gainst which the wild waves beat,
 I hold my dreary, joyless seat,
 Far distant from my native land;
 Nor nuptial bed is mine, nor child, nor friend.
 At Argos now no more I raise
 The festal song in Juno's praise;
 Nor o'er the loom sweet sounding bend,
 As the creative shuttle flies,
 Give forms of Titans fierce to rise,
 And dreadful with her purple spear
 Image Athenian Pallas there.
 But on this barbarous shore
 Th' unhappy stranger's fate I moan,
 The ruthless altar stained with gore,
 His deep and dying groan;
 And for each tear that weeps his woes,
 From me a tear of pity flows.”

Orestes, the brother of Iphigeneia, had avenged upon his mother the murder of his father. For this he was driven by the Furies. While stretched before the shrine of Phoebus he heard the divine voice from the golden tripod, commanding him to speed his way to the wild coast of the Taurians, thence to take by fraud or by fortune the statue of Diana that fell from heaven, and carry it to Attica. Doing this he should have rest from the Furies.

He was captured, however, along with his friend Pylades, and brought to the altar to be sacrificed. The relationship of the brother and sister became here revealed, and they together fled, carrying with them the image. It was not without a struggle that they reached the shore, but finally,

“ On his left arm sustained
 Orestes bore his sister through the tide,
 Mounted the bark's tall side and on the deck
 Safe placed her and Diana's holy image
 Which fell from heaven.”

Neptune favored the Greeks, Minerva forbade pursuit, and the image was borne to Halae (or as some said to Brauron) in Attica.

Cicero spoke of the Trojan Palladium as something that fell from the sky;—*quod de coelo delapsum*. Other classical writers, notably Ovid, speak of it in similar terms. The story

in its various forms points toward a stone-fall as its basis. One form of it runs thus :—

Pallas and her foster sister Athena were wrestling with each other, when Pallas was accidentally killed. In grief Athena made an image of Pallas and set it up on Olympus. When King Ilus was about building his city on the Trojan plain he prayed for a favorable omen. In response to his prayer Jupiter cast this image down at the feet of the suppliant king. In the new city it was set up in a temple specially erected to contain and protect it. So long as Troy could keep safely this image, the city, it was firmly believed, could not be taken by its foes.

According to one story the Greeks stole the image before capturing the city. As many cities afterwards claimed to possess the treasure as claimed to be the birthplace of Homer. According to the Romans, Aeneas carried the Palladium to Italy, and the image was regarded as the most sacred treasure of the Roman State. For centuries even in historic times it was so carefully kept by the Vestal Virgins that the Pontifex Maximus was not allowed to see it.

We naturally have doubts about the nature, or even the existence, of an object so kept out of sight. What it was that the Vestals thus guarded, or whether they had anything to represent the image of Pallas, will probably never be known. But it is far otherwise with another famous object of Roman worship. To the east of the Trojan plain on which the Palladium fell rise the mountains of Phrygia and Galatia. In Pessinus, near the border line of these two countries, and in the caves and woods near Pessinus, the goddess Cybele, the mother of the great gods, Jupiter, Neptune, and Pluto, was specially worshiped. This worship may not have been more degrading than the worship of many other Asiatic divinities. But it was wretched and unmanly almost beyond our possible conception. It furnished to Catullus the theme for the most celebrated of his poems, one of the strongest pictures in all literature. The Grecian athlete entered her service with joyful music and dancing. Too late he looks back from the Asiatic shore, out of his hopeless degradation, on the nobleness of his former Grecian life. The lion of Cybele drives him in craven fear again into the wild woods, to spend his days in the menial servitude. The Roman poet exclaims, "O goddess, great goddess Cybele, goddess queen of Dindymus; far from *my* house be all thy frenzies; others, others, drive thou frantic."

At some unknown early time a meteoric stone fell near to Pessinus. It was taken to the shrine of Cybele and there set up and worshiped as her image. This image and its worship

very early attained a wide celebrity. About two hundred years before Christ, in the time of the second Punic war, the stone was transported to Rome. The detailed history of the transfer is given by several writers in varied terms. It forms one of Livy's charming stories, it is told in poetic terms by Ovid, it is given as a tradition by Herodian. For every detail of the history I do not ask confiding belief, but the principal event is, I suppose, historically true.

In the year 205 before Christ Hannibal had, since crossing the Alps, been holding his place in Italy for more than a dozen years, threatening the existence of the Roman State. The fortunes of war were now somewhat adverse to the Carthaginian general. A shower of stones alarmed the Romans. The decemvirs consulted the Sybilline books, and there found certain verses which imported that whensoever a foreign enemy shall have carried war into the land of Italy he may be expelled and conquered if the Idæan mother be brought from Pessinus to Rome. These words were reported to the Senate. Encouraging responses came at the same time from the Pythian oracle at Delphi.

The Senate set about considering how the goddess might be transported to Rome. There was then no alliance with the states of Asia. But King Attalus was on friendly terms with the Romans because they had a common enemy in Philip II. of Macedon. The Senate, therefore, selected an imposing embassy from the noblest Romans. A convoy of five quinqueremes was ordered for them, that they might make an appearance suited to the grandeur of the Roman people. The embassy landed on their way and made inquiry of the oracle at Delphi, and were informed "that they would attain what they were in search of by means of King Attalus, and that when they should have carried the goddess to Rome they were to take care that whoever was the best man in the city should perform the rite of hospitality to her." The king received them kindly, but refused their request, whereupon an earthquake tremor shook the place and the goddess herself spoke from her shrine, "It is my will, Rome is a worthy place for any god; delay not." The king yielded; a thousand axes hewed down the sacred pines, and a thousand hands built the vessel. The completed and painted ship received the stone and bore it to the mouth of the Tiber.

It was the spring of the following year before the ship arrived. Meanwhile new prodigies frightened the people. A brilliant meteor had crossed Italy from east to west, a little south of Rome, and a heavy detonation followed. From this, or from some other meteor, another shower of stones had fallen. In expiation, according to the custom of the country

in case of stonefalls, religious exercises during nine days were ordered. The Senate after careful deliberation selected one of the Scipios, deciding that he of all the good men in the city was the best, and they deputed him to receive the stone. The whole city went out to meet the goddess. Matrons and daughters, senators and knights, the vestals and the common people all joined the throng. But a drought had reduced the water of the Tiber so that the vessel grounded upon the bar. All the efforts of the men pulling upon the ropes failed to move it. A noble matron who had been slandered stepped forward into the water. Dipping her hands three times into the waves and raising them three times to heaven, she besought the goddess to vindicate her good name if she had been unjustly slandered. She laid hold of the rope and the vessel followed her slightest movement, amid the plaudits of the multitude.

Scipio, as he had been ordered by the Senate, waded out into the water, received the stone from the priests, carried it to the land, and delivered it to the principal matrons of the city, a band of whom were in waiting to receive it. They, relieving each other in succession and handing it from one set to another, carried it to the gates of the city, and thence through the streets to the temple of Victory on the Palatine Hill. Censers were placed at the doors of the houses wherever the procession passed, and incense was burned in them, all praying that the goddess would enter the city with good-will and a favorable disposition. The people in crowds carried presents to the temple. A religious feast and an eight days' festival with games were established to be celebrated thereafter each year in the early part of April.

Before another year had passed Hannibal, after having maintained his army in Italy for fifteen years, was forced to withdraw again to Africa. From the liberal offerings of the people, in gratitude for deliverance, a temple was erected to Cybele, long known as the Temple of the Great Mother of the Gods, so that twelve years after its arrival at Rome the stone was taken from the Temple of Victory and set up in its new home. A silver statue of the goddess was constructed, to which the stone was made to serve in place of a head. Here, in public view, for at least five hundred years that stone was a prominent object of Roman worship. Its physical appearance is described by several writers. It was conical in shape, ending in a point, this shape giving occasion to the name *Needle of Cybele*. It was brown in color, and looked like a piece of lava. Arnobius, a Christian writer just before the accession of Constantine, and over five hundred years from the date of its arrival at Rome, says of the stone :

“If historians speak the truth and insert no false accounts

into their records, there was brought from Phrygia, sent by King Attalus, nothing else in fact than a kind of stone, not a large one, one that could be carried in a man's hand without strain, in color tawny and black, having prominent, irregular, angular points, a stone which we all see to-day, having a rough irregular place as the sign of a mouth, and having no prominence corresponding to the face of an image." Arnobius goes on to ask whether it was possible that this stone drove the strong enemy Hannibal out of Italy,—made him who shook the Roman State, unlike himself, a craven and a coward.

Just when this stone disappeared from public view I do not know. In directing the recent excavations on the Palatine Hill, Prof. Lanciani was at first in great hopes of finding it;—because it had no intrinsic value to the many spoliators of Rome, nor to the former excavators of Roman temples. But the place in which he expected to find it was absolutely empty. At a later date, however, he found in a rare volume an account of excavations made on the Palatine Hill in 1730, in which the private chapel of the Empress was found and explored. In this we perhaps have an account, and it is to be feared, the last account of a sight of the Cybele stone. The writer says: "I am sorry that no fragment of a statue, or bas-relief, or inscription has been found in the chapel, because this absence of any positive indication prevents us from ascertaining the name of the divinity to whom the place was principally dedicated. The only object which I discovered in it was a stone nearly three feet high, conical in shape, of a deep brown color, looking very much like a piece of lava, and ending in a sharp point. No attention was paid to it, and I know not what became of it." This description is almost identical with that given by Arnobius and others of the stone from Pessinus.

Another stone of meteoric origin was brought to Rome, and there for a brief period was most fantastically worshipped. This was near the beginning of the third century after Christ. It came like the other stones of which I have spoken from Asia. In the City of Emesa, on the banks of the Orontes about midway between Damascus and Antioch, there was in those days a magnificent temple of the Sun. A gorgeous worship was maintained before a stone that fell from heaven, that served as the image of the Sun-god. The description of it is not very unlike that of the Cybele meteorite. Herodian, who probably saw it, says: "It is a large stone, rounded on the base, and gradually tapering upward to a sharp point; it is shaped like a cone. Its color is black, and there is a sacred tradition that it fell from heaven. They show certain small prominences and depressions in the stone, and those who see them persuade their eyes that they are seeing an image of the sun not made by hands."

This Sun-god was named Heliogabalus, and before the altar a boy of nine years of age began to serve as priest. Such a Syrian service did not make the boy grow manly nor virtuous, and when at the age of fifteen he became emperor through the money and intrigues of his grandmother, and the murder of the Emperor Macrinus, we have for three years at Rome the view of the sorriest scrapegrace that ever sat on a throne. He assumed with the name of Antoninus also the name of his god Heliogabalus. To the great disgust of the Roman Senate and people, he brought with him from Syria the image of his god, the sacred stone, and himself continued before it his priestly service with all its fantastic forms and gesticulations. He built within the city walls a grand and beautiful temple, with a great number of altars around it; he repaired thither every morning, and sacrificed hecatombs of bulls and an infinite number of sheep, loading the altars with aromatics, and pouring out firkins of the oldest and richest wines. He himself led the choruses, and women of his own country danced with him in circles around the altars, while the whole Senatorian and Equestrian orders stood in a ring like the audience of a theater.

But now he must have a wife for his god. So he broke into the apartments guarded by the vestals and carried to the palace the Trojan Palladium, or what he supposed was that object, and was intending to celebrate the nuptials of the two images. His god, however, he concluded would not be pleased with a warlike wife like Pallas, therefore, he ordered brought from Carthage an ancient image of Urania, or the Moon, which had been set up by Dido when she first built old Carthage. With this image he demanded the immense treasures in her temple, and he also collected from every direction immense sums of money to furnish to the Moon a suitable marriage portion when married to the Sun.

He built another temple in the suburbs of Rome, to which the Emesa stone, the god (?) was carried in procession every year, while the populace were entertained with games, and shows, and feastings and carousings. Herodian thus describes this performance:

“The god was brought from the city to this place in a chariot glittering with gold and precious stones, and drawn by six large white horses without the least spot, superbly harnessed with gold and other curious trappings reflecting a variety of colors. Antoninus himself held the reins—nor was any mortal permitted to be in the chariot; but all kept attendant around him as charioteer to the deity, while he ran backward leading the horses, with his face to the chariot, that he might have a constant view of his god. In this manner he performed

the whole procession, running backwards with the reins in his hands, and always keeping his eyes on the god, and that he might not stumble or slip (as he could not see where he went), the whole way was strewn with golden sand, and his guards ran with him and supported him on either side. The people attended the solemnity, running on each side of the way with tapers and flambeaux, and throwing down garlands and flowers as they passed. All the effigies of the other gods, the most costly ornaments and gifts of the temples, and the brilliant arms and ensigns of the imperial dignity, with all the rich furniture of the palace, helped to grace the procession. The horse and all the rest of the army marched in pomp before and after the chariot."

The reign of a foolish boy at this period of Rome's history was necessarily a short one, and at the age of eighteen the soldiers killed him and let the Roman populace have the body to drag through the city streets. The worship of the Sun-god at once ceased, and, no doubt, the stone also was thrown away. The Cybele stone, however, remained an object of public worship, since the quotation from Arnobius, which I have given, was written nearly a century later than the reign of Heligabalus.

I propose to speak briefly of one more meteorite whose worship has had a world-wide fame;—the image of the Ephesian Artemis. This worship had its center at Ephesus, but was widely extended along the shores of the Mediterranean. Temple after temple was built on the same site at Ephesus, each superior to the preceding, until the structure was reckoned one of the seven wonders of the world. As a temple, it became the theatre of a most elaborate religious ceremonial. As an asylum, it protected from pursuit and arrest all kinds of fugitives from justice or vengeance. As a museum, it possessed some of the finest products of Greek art, notably works of Phidias and Apelles. As a bank, it received and guarded the treasures which merchants and princes from all lands brought for safe keeping. In its own right it possessed extensive lands and large revenues. The great City of Ephesus assumed as her leading title that of *νεωκόρος*, or temple-warden of Artemis, putting this name on her coins, and in her monumental inscriptions.

The image, which was the central object in this temple, was said to have fallen from heaven. Copies of it in all sizes and forms were made of gold, of silver, of bronze, of stone and of wood, by Ephesian artificers, and were supplied by them to markets in all lands. What a lifelike picture is given us in the 19th chapter of the Acts of the Apostles, of the excited crowd of Ephesians, urged on by the silversmiths, who made for sale

the silver shrines of the goddess, and who saw that their craft was in danger if men learned to regard Artemis as no real divinity, and to despise the image that fell down from the sky.

We cannot suppose that the Ephesian Artemis image of the first century was a meteorite, though we have the distinct appellation, Diipetes, fallen from the sky. But I believe that there was a meteoric stone that was the original of the Ephesian images, and it seems not at all improbable that in some one of the destructions of the temple it disappeared. Or, in the progress of time, there may have been a desire to represent the goddess in a more artistic form than the shapeless stone afforded.

Many forms of the Ephesian Artemis are still preserved, and they have, amid all their variations, a certain peculiar character in common. That common character seems to me to confirm the statement that the original image fell from heaven. This goddess is regarded, let me say, as different from the Grecian Artemis, the beautiful huntress so well known in Greek art, and I am speaking only of the images of the Ephesian Artemis.

There is one peculiarity in the outward forms of the meteorites that is characteristic of nearly all of them. I mean the molded forms, and the depressions all over the surfaces. They are better appreciated by being seen, than by any description I can give you. They are common to meteorites of all kinds, from the most friable stone to the most compact iron. (I show you one, a stone from Iowa—also the plaster cast of another, a stone from some fall, I know not which one.) Those who have recently visited the collection in the Peabody Museum may recollect the model of an iron that fell two or three years ago in Arkansas, which displays most beautifully these depressions.

Let now an artist attempt to idealise any one of these molded forms, and to make something like a human shape out of one of them. He must necessarily set it upright, and he must give it a head. You have then a head surmounting one of these molded forms. Let now the convenience and the taste of the artificers of the images have some liberty to act—and we know that they did act, for we have considerable variety in these images—and a development in the conventional representation of the image is sure to follow.

[The lecture closed with the exhibition of a series of lantern pictures showing the forms of some typical meteorites.]

ART. II.—*The Spectra of Argon*; by JOHN TROWBRIDGE
and THEODORE WILLIAM RICHARDS.

It is well known that argon possesses at least two marked spectra—one, termed the red, which is chiefly characterized by red lines; and another called the blue, which, as its name signifies, is strongly marked by blue lines.

In studying these spectra by means of a high tension accumulator, we have been led to observe carefully the electrical conditions necessary for producing them. It is obvious that a battery of a large number of cells is the most suitable source for the study of discharges of electricity through gases. Especially is this true of a storage battery; for the readiness with which it can be charged by a dynamo, the constancy of the electromotive force (about 2.1 volts per cell), the ease with which it can be coupled for quantity or tension; and the steadiness of the discharge afforded by it, make such a battery far superior to an induction coil or to an electrical machine.

With an induction coil the discharge is not unidirectional and is affected by the necessary irregularities of the break. These irregularities make themselves felt in a marked degree when a condenser is used in the secondary circuit. The electrical machine gives an intermittent current, and has a varying capacity. The advantages of a battery for the study of the discharge of electricity through gases have been pointed out by De la Rue and Miller and by Hittorf.* These investigators worked with voltaic cells which were not constant and which required great oversight and continual renewals. In our investigations we are using a lead accumulator of the Planté type; and we find it highly advantageous for spectroscopic work; for by means of the steady current afforded by it, one can study the spectra of gases under especially good conditions.

Our battery consists of five thousand cells, so arranged that they may be disconnected and wholly reconnected in any desired manner in less than a minute. The electromotive force of the complete series is somewhat over ten thousand volts, but when the cells are connected for quantity, they may be readily charged by means of a dynamo giving a tension of only sixty volts. The insulation of the terminals of this battery was a matter of some difficulty, for even dry wood allows considerable leakage from one case of cells to another; but by the plentiful use of paraffin, mica, and vulcanite, the problem was solved with reasonable success. The discharge from only a very small fraction of the battery produced a most uncom-

* Ann. der Phys. und Chem. (N. F.), vol. vii, 1879, p. 553.

portable shock, and it is probable that the discharge of the whole battery would be instantly fatal. The great heat of this full discharge immediately shatters a Geissler tube, the glass being splintered throughout the whole length of the capillary. Hence a resistance of several million ohms was usually interposed between the battery and the rest of the apparatus. This resistance was also of service in protecting the experimenters from serious accidental shocks. Ordinary distilled water contained in long tubes with movable electrodes was the most convenient resistance for our purpose; dilute solutions of cadmic iodide in amyl alcohol and of cadmic sulphate in water between cadmium electrodes, were also sometimes used. Unless these liquids are contained in tubes of rather large diameter, they are likely to cause irregularities by boiling under the influence of the heat of the current. Graphite resistances are too combustible for the purpose.

The argon used in our experiments was very kindly given to one of us by Lord Rayleigh. It was a portion of the purest preparation which had been used in his final determinations of the density of the gas; and our tubes were carefully filled with it by the kindness of F. O. R. Götze, of Leipzig. The preliminary work described in this paper was chiefly done with a single tube containing gas at a pressure of about 1^{mm} . The tube had a wide capillary and was about 15^{cm} in total length. In such a tube, the red glow of argon is readily obtained with a voltage of about two thousand, but not with much less. A higher tension of gas demands a higher tension of electricity in order to start the discharge, no matter how much or how little other resistance is interposed; but when the glow has once started it is continued by means of a much smaller electromotive force. This is shown by the fact that a Thomson electrostatic voltmeter, connected with the terminals of the Geissler tube, indicated differences of potential between the ends of the tube ranging from six hundred and thirty volts upward. De la Rue and Miller, who found no potential difference between the ends of Geissler tubes, must have been working with discontinuous discharges. Crookes's estimate that 27,600 volts are necessary to produce the red spectrum is evidently excessive.

The introduction of a capacity between the terminals of the Geissler tube, for example, two plates of metal sixteen hundred square centimeters in area separated by plate glass one centimeter thick, made no difference in the red glow, so long as the connections were good and the condenser quiet.* As soon as a spark gap was introduced, or the condenser began to

* Sir W. Thomson (Lord Kelvin): *Papers on Electrostatics and Magnetism*. MacMillan, 1872, p. 236.

emit the humming sound peculiar to it, the beautiful blue glow so characteristic of argon immediately appeared.

If this light is examined by a revolving mirror it is seen to consist of intermittent discharges. The battery charges the condenser to the potential necessary to produce a spark between the terminal of the spark gap. The discharge of this accumulated electricity is produced in the tube and then the operation is repeated. The time interval between the discharges is evidently a function of the capacity of the condenser, as well as of the electromotive force of the battery and the resistance between it and the condenser.

The accurate determinations of the potential and current strength of the intermittent blue discharge is a matter of some difficulty; and at present we feel hardly in position to make a definite statement regarding these measurements. However, the potential required certainly cannot be greater than two thousand volts,—the electromotive force of the battery which will easily produce the blue glow. Here again, Crookes's estimate of far above 27,000 volts was very much too large.

Since it is necessary to employ a condenser to produce the blue spectrum of argon, we were led to examine the electrical conditions which are necessary for the discharge. In the circuit with the tube containing argon, between the tube and one of the plates of the condenser, we first interposed a small coil of about eight ohms resistance, having a self-induction of $\cdot 015$ of a henry. The blue glow changed to the red glow. We then modified the self-induction and discovered that even the self-induction of the leads to the tube, which consisted of a few feet of uncoiled wire, undoubtedly modified the blue discharge, for an amount of induction equivalent to $\cdot 000051$ henry had a marked effect in diminishing the brilliancy of the blue glow.

A comparatively small ohmic resistance substituted for the impedance of the self-induction between the tube and one plate of the condenser produced precisely the same effect as this coil, causing a complete transformation from blue to red. The change from blue to red is so marked that a tube of argon may well serve as an inductometer of some sensitiveness, as well as a means of comparing the influence of self-induction with ohmic resistance. The effect of impedance or resistance must be to prolong or to damp the oscillations of the condenser discharge. Indeed, the resistance of the tube itself may be so great as to damp the oscillations without the need of the introduction of outside resistance or self-induction; therefore argon at high tension gives the red glow with a condenser and rate of oscillations which are quite capable of producing the blue glow in a tube of lower tension.

Kayser* criticises Crookes's statement that a condenser and a spark gap are necessary for the production of the blue spectrum. He finds that with a lower pressure in the tube than 2^{mm} the blue spectrum can be readily obtained without condensers and spark gaps. He also states that it is much easier to produce the pure blue spectrum than the pure red. In order to obtain the red spectrum the strength of the current must be adapted to the gas pressure. Kayser employed an induction coil. The condenser, however, in the primary of an induction coil sends an oscillatory discharge through the secondary. Although Kayser did not employ a condenser in the manner recommended by Crookes, he still had a condenser in his electrical system and the resistance of his Geissler tube was probably so proportioned that the secondary circuit was in resonance with the primary circuit. To prove this we placed a tube containing argon across the terminals of the secondary of an induction coil, and having removed the condenser attached to the primary, we sent the discharge through the tube by means of a break in the induction coil. The light of the discharge was red, and when it was examined by a revolving mirror no trace of blue was seen in the capillary portion of the tube. An adjustable condenser and a variable induction were then placed in the primary circuit. By varying the amount of the capacity together with the self-induction in the primary system, the discharge in the secondary, when examined by a revolving mirror, was seen to consist of both red and blue discharges. The red glow was evidently due to a unidirectional discharge and the blue to an oscillatory discharge. The unidirectional discharge was caused by the failure of the breaks to charge the condenser to the primary, or by increased resistance in the tube. When, however, the condenser was charged, it immediately discharged in an oscillatory manner; and the secondary coil responded by resonance. The rarified argon thus shows in an interesting manner what is the function of the condenser in the primary of an induction coil. It serves to send oscillatory discharges through the primary circuit; and the greatest effect is obtained in the secondary circuit when it is in resonance or in tune, so to speak, with the primary.

The presence of a condenser was necessary to form the blue glow in Kayser's work, only when the resistance of his tube and the self-induction of his coil together were enough to damp the discharge of the small capacity of the coil. He could have obtained the pure red in any case by interposing, as we have done, a resistance or self-induction between the condenser and the tube, although our other resource for obtaining

* Sitzungsberichte der königlich preussischen Akad. der Wissenschaften zu Berlin, May 7, 1896.

the red glow in any tube from the continuous discharge of a constant battery was apparently not open to him.

By taking out all resistances except the spectrum tube, and sending an exceedingly strong current through the tube for very brief intervals of time, we have been able to cause the blue glow; but it seems probable that under these conditions the capacity of the battery itself engenders oscillations which are no longer damped by interposed resistance. Whether the blue glow with its accompanying change of spectrum is due merely to the great quantity of electricity discharged in a very short space of time, or to some property intrinsic in the to-and-fro motion of the oscillatory discharge, is a question, which we hope soon to answer. The red glow, if caused by oscillations at all, must be caused by oscillations within the Geissler tube itself;* for all outside oscillations are cut off by the large resistance between the battery and the tube.

The effect of the oscillatory discharge in producing the blue spectrum of argon can also be shown by the use of an electrical machine. If the terminals of the tube containing argon are connected with the terminals of an electrical machine, the pure red spectrum is obtained. If a spark gap is interposed in such a manner that a condenser charged by the machine can discharge through the tube, the blue discharge immediately results. The condenser discharge oscillates through the gas.

The oscillatory discharge of the condenser is evidently an important factor in producing the blue spectrum of argon. According to Lord Kelvin's law, if R denotes the resistance of the circuit, L , the self-induction, and C the capacity of the circuit, the discharge of the condenser becomes non-oscillatory when

$R = \sqrt{\frac{4L}{C}}$. It may be, therefore, that an estimate of the

resistance in the tube can be obtained by measuring the self-induction which is required to change from the blue discharge to the red.

When the tube containing argon at a suitable pressure is brought near a Hertz oscillator, giving a rate of about 115,000,000 oscillations per second, it immediately shows the blue color. In this case the oscillator consisted of two zinc plates about 40^{cm} square with a spark gap between them. The capacity and impedance of the circuit was extremely small.

The unusual sensitiveness of an argon tube to oscillatory discharges leads us to believe that it will be of great use in the study of wave motions of electricity. As we have seen, it is competent to show when the Hertz oscillator is working properly, that is, sending forth electrical oscillations and not unidi-

* *Ann. der Physik und Chemie*, 1893, vol. xlviii, 549, Ebert and E. Wiedemann.

rectional discharges. The change of color in the tube from red to blue is so marked that an argon tube reveals what is not shown in a conspicuous manner by other gases. We have thought that this remarkable property of an argon tube is worthy of being distinguished by a name which might describe it and we have, therefore, called an argon tube fitted for the study of electrical waves a talantoscope (*ταλάντωσις*).

In an oscillatory discharge the molecules receive powerful electrical impulses of opposite sign. These impulses are separated, it may be, by millionths of a second. It is significant that the shorter wave lengths of light accompany these electrical oscillations. It is our purpose to extend our study of the effect of electrical oscillations through more highly rarified media in which arise the Röntgen rays. These rays are probably highly modified by the oscillatory discharge. A battery of a large number of cells now at our command will afford the best means of studying this subject: for its discharges, as we have pointed out, are free from the fluctuating effects produced by induction coils, transformers and electrical machines. Our present paper is, therefore, only preliminary to a more exhaustive study of the discharges of electricity through rarified gases, by means of a storage battery of ten thousand cells, which will give an electromotive force of about twenty thousand volts.

Harvard University, Dec. 1st, 1896.

ART. III.—*Some Queries on Rock Differentiation*; by
GEO. F. BECKER.

Hypothesis of differentiation.—As I understand the theory of what is called the differentiation of rock magmas, now so generally held by lithologists, its outlines may be expressed in the following terms: In some extensive districts the massive rocks are found to possess similarities of composition, and such rocks have been called consanguineous. This consanguinity might be accounted for by supposing an originally homogeneous magma to have undergone partial segregation into fluid portions of distinctly different yet allied composition, prior to eruption, and this is the process called differentiation. It is also known by observation in the laboratory, that if a more or less complex, homogeneous solution be exposed to certain physical conditions, segregation into distinct portions may take place. It is hence inferred that such is actually the history of consanguineous rocks.* By a slight extension of this inference most massive rocks are regarded as resulting by differentiation from a generalized magma.

The existence of distinct though allied rocks locally associated with transitional varieties is undisputed. The validity of the explanation offered by the modern school for these occurrences is another matter. The hypothesis of differentiation is extremely attractive and if it were substantiated would lead to a well organized system of rock investigation. It may also be correct; but there are respects in which it appears to be in need of much explanation, and it does not seem certain that the fundamental postulate of originally homogeneous magmas of vast volume is well established.

Possible modes of segregation.—The segregation† of a homogeneous fluid into distinguishable portions under the influence of varying temperature or pressure may take place by different methods. An increase or decrease in the concentration of certain components may occur in the cooler part of the fluid or in that portion which is under greatest pressure. There are also cases in which solutions which are homogeneous

* The early literature bearing on this subject, together with fresh contributions, is given in Mr. Arnold Hague's work on the Geology of the Eureka district, U. S. Geol. Survey, Mon. 20, 1892, p. 267 et seq. Some of Prof. J. P. Iddings' papers bearing on the subject are: the Crystallization of Igneous Rocks, 1889; Electric peak and Sepulchre mountain, 1891; the Origin of Igneous Rocks, 1892, etc. The latest of Prof. W. C. Brögger's contributions is: die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo, 1895.

† The term differentiation is ambiguous. In the older, and as it seems to me the more proper sense, differentiation is the discrimination of existing differences. One differentiates lime-soda feldspars by their angles of extinction.

at one temperature tend to separate at some other temperature into two or more immiscible fluids, or into a fluid portion and a solid one. There seem to be no other conceivable ways in which segregation or differentiation under purely physical influences can take place, and it is one of the purposes of this paper to examine the mechanism of these processes in the light of the modern conclusions of chemical physics.

It will be most convenient to consider first those cases in which only miscible liquids, or liquids present only in miscible proportions, are concerned, reserving consideration of immiscibility and insolubility for subsequent discussion.

The differentiation of a homogeneous magma, or its segregation into distinct though related miscible fluids, involves relative movement of the particles of the magma. This movement cannot take place in visible streams or currents, such as would result from convection; for if a tendency to segregation existed, stirring would neutralize or overcome it. Segregation might, however, be accomplished by what may be called *molecular flow*, this term being understood to mean the progressive translation of portions of a liquid, molecule by molecule, among the similar or dissimilar molecules of the remainder of the liquid.

Instances of molecular flow.—Molecular flow is exhibited in ordinary diffusion, in osmosis, and in some cases of the segregation of fluids. Although these are seemingly very different manifestations, they are all reducible to the tendency which fluids exhibit to attain a condition of stable equilibrium, through an equalization of the partial pressures of each component in different parts of the fluid.

If two liquids which are miscible in all proportions but are chemically indifferent to one another are placed in a small closed vessel and are maintained at a constant temperature, each diffuses into the other, and the flow of molecules will never cease until the mixture is uniform throughout, so that each liquid occupies the volume formerly occupied by both. If two such liquids are each soluble in a third, each will diffuse into the solvent at its own peculiar rate, and in such cases mere diffusion produces partial separation of the dissolved substances. At any given time the substance which diffuses more rapidly will be found in greater relative abundance at any point at all distant from the original surface of diffusion. Thus Graham in experimenting on the diffusion in water of a solution which contained 5 per cent of common salt and 5 per cent of sodium sulphate found that the upper layer of water after a certain interval contained ten times as much of the chloride as of the sulphate.

In this case any one layer of the water may be regarded as a kind of septum through which the chloride diffuses at a higher rate than does the sulphate. There are many septa more efficient in separating solutions than is water. Especially familiar is bladder, through which one class of compounds (the crystalloids) passes very readily, while another (the colloids) passes with difficulty. Here indeed the material of the septum perhaps has some molecular action on the solutions, and if so the explanation is thereby complicated. Nevertheless osmosis is regarded by physicists as a case of ordinary diffusion complicated, as some think, by the molecular action of the septum.*

There is another class of septa which seems to be without molecular action and behave as mere "atomic sieves." They are wholly impermeable to some solutions (bladder is not) and easily permeated by others. By means of these "semi-permeable" septa, which are produced by precipitation, it has been found that the molecular flow of a given solution continues until a certain definite pressure exists on one side of the septum, this pressure being characteristic of the substance experimented upon and independent of the nature of the membrane. This is the "osmotic" pressure of the dissolved substance, and Mr. van't Hoff has shown† that it is equal to the pressure which would be exerted by the substance in a gaseous state when occupying the same volume at the same temperature. Evidently then there is a very close analogy between gases and substances in a state of solution, and it is in fact now well recognized that, as van't Hoff pointed out, they obey several of the same fundamental laws when osmotic pressure and simple pressure are considered as interchangeable terms.‡

Mr. W. Nernst§ has discussed the phenomena of simple diffusion in their relation to osmotic pressure and is led to the conclusion that osmotic pressure is the force immediately concerned in the diffusion of liquids, just as the pressure exerted by a gas in confinement is the cause of the diffusion of gases.

The most important case of molecular flow for the purposes of this discussion arises when a homogeneous solution is heated at the top. Molecular flow then takes place from the top

* Tait: *Prop. of Matter*, 2d ed., p. 275. It is probable that the osmotic action of animal membranes is exactly the same in principle as that of precipitated ones. They are both "atom sieves," only the "meshes" are of a different size, perhaps. If any "molecular action" (whatever that may be) exists in one case, it probably does in the other also. The evidence of such action is not distinct.

† *Zeitschr. phys. Chem.*, vol. i, 1887, p. 481.

‡ The osmotic pressure is inversely proportional to the volume of the fluid in a given space. The osmotic pressure at constant volume is proportional to the absolute temperature. Solutions of equal volume of different substances which contain equal numbers of molecules at equal temperatures exert equal osmotic pressure. These laws correspond to those of Boyle, Gay-Lussac and Avogadro.

§ *Zeitschr. phys. Chem.*, vol. ii, 1888, p. 613.

towards the bottom, so that a concentration of the substance in solution occurs in the lower portion. This fact appears to have been observed first by Mr. C. Ludwig in 1856* and was subsequently studied by Mr. Ch. Soret.† The phenomenon has been explained by Mr. van't Hoff.‡ The osmotic pressure of a substance in solution is proportional to the absolute temperature. Hence there is a resultant pressure in an unequally heated fluid which is directed towards the cooler portion, and this will not be equilibrated until the osmotic pressure in the cooler portion is appropriately increased. Now the osmotic pressure is proportional to the concentration as well as to the temperature; and the condition of equilibrium is therefore that the concentrations should be inversely as the absolute temperatures. Thus if a magma were heated to $T = 1500^\circ$ at the top while the bottom of the mass were kept at $T = 1400^\circ$, the concentration of the substances dissolved in the magma would increase until that at the bottom were $15/14 = 1.07$ of that at the top. Mr. van't Hoff's theory of this case agrees somewhat roughly but substantially with Mr. Soret's experiments.

The solution of any substance in a fluid is attended by a change in the total volume. When this change is a decrease in volume, solubility increases with increasing pressure; and vice versa. Hence in a deep mass of solution of constant temperature there is believed to be a tendency to concentration through pressure at the bottom or the top of the mass. The change of concentration, however, would be so small that physicists are not hopeful of demonstrating it experimentally. The thermodynamical discussion of Messrs. Gouy and Chapron§ seems to show that even in vessels 100 meters in depth the effect of gravity on sodium chloride solution would influence concentration only to the extent of a fraction of 1 per cent, the concentration being greater at the bottom. It is evident that the process by which concentration is effected is molecular flow. Further remarks on the variability of solubility with pressure will be made in discussing the properties of immiscible fluids.

There is no question that molecular flow does play a part in lithogenesis. One may often see blebs or smears of matter in either granular or porphyritic rocks which have manifestly undergone at least superficial solution, the rock around the bleb showing an aureole of diffusion. So, too, crystallization in many cases is explicable only by the molecular flow of a cer-

* Wien Sitz. Ber., vol. xx, 1856, p. 539.

† Comptes Rendus, Paris, vol. xci, 1880, p. 289.

‡ Zeitschr. phys. Chem., vol. i, 1887, p. 487.

§ Ann. de ch. phys. (VI), vol. xii, 1887, p. 384.

tain ingredient to one spot from the adjacent mass. There is absolutely no theoretical reason why such processes should not occur, for at very short distances molecular flow is a very rapid process, as will be explained presently. On the other hand, it is questionable whether masses of rock of hundreds of meters in thickness could be thus separated, even if the time allowed for completion of the process were equal to an entire geological period.

Character of diffusion.—It has been explained above that all the processes of molecular flow are reducible to the same elementary action, viz: movements due to differences of osmotic pressure. This kind of flow is most simply manifested in ordinary diffusion, and it is also in the ordinary diffusion of concentrated solutions that molecular flow takes place most rapidly. It is possible to bring an indefinitely large mass of an absolutely and permanently concentrated liquid in contact with another liquid in which the first is thoroughly soluble. Under these conditions, the resultant osmotic pressure being proportional to concentration, must have its highest value, and molecular flow (measured by the amount of substance passing through a given area in a given time) must be greater than it otherwise can be. Think, for example, of a tall vessel at the bottom of which is a layer of solid sulphate of copper, the rest of the vessel being full of pure water. Then a concentrated solution of the sulphate will form in contact with the solid sulphate and this layer will continue concentrated until solution is complete. Diffusion will then proceed as rapidly as it can do at the temperature of the experiment. Under such conditions the amount of a dissolved substance which diffuses through an area of one square centimeter in one second, when the gradient of concentration (perpendicular to the area) is one gram of substance per cubic centimeter of fluid per centimeter of distance, is a constant called the "diffusivity" of the substance in water.* In the case of gases Maxwell showed that a simple numerical relation exists between the diffusivity of substance, the diffusivity of energy or heat, and the diffusivity of momentum which gives rise to viscosity.† In the case of fluids the *a priori* determination of these constants is not yet possible and they must be found by experiment.

When this constant called diffusivity of substance is determined, the process of diffusion can be accurately predicted under uniform conditions of temperature and pressure at least for weak solutions. In 1855 Prof. A. Fick‡ advanced the hypothesis that the time rate at which a salt diffuses through a

* Tait: Prop. of Matter, 2d ed., 1890, p. 271.

† Theory of Heat, 1894, p. 332, and Nature, vol. viii.

‡ Pogg. Ann., vol. xciv, 1855, p. 59.

stated area is proportional to the difference between the concentrations of two areas infinitely near one another. This is, *mutatis mutandis*, the same law which underlies Fourier's treatment of heat conduction.* Very extended researches by many physicists have confirmed Fick's law, excepting for very strong solutions, and therefore also the applicability of Fourier's mathematical developments concerning conduction to the elucidation of diffusion. It can be shown that Fick's hypothesis would be strictly applicable to solutions of any concentration if Pfeffer's law, that osmotic pressure and concentration are proportional, were exact. But this law corresponds to Boyle's law that gaseous pressure and volume are inversely proportional, and this, as every one knows, is exact only when the number of molecules per unit volume is not too great. At least two influences tend to render Pfeffer's law and Fick's hypothesis inexact for high concentration. There is a tendency to change of molecular weight with increasing concentration, a species of polymerization, and this would be attended by decreased diffusibility. When there is no such aggregation there is an increase of diffusibility, due, it is thought, to the attraction between the solvent and the dissolved substance.

While it is proper to point out the deviation of very strong solutions undergoing diffusion from the law of Fick, this deviation is of importance only near the contact from which diffusion takes place, and not always then. For if a solvent dissolves a salt only to a limited extent, even a saturated solution may be a weak one, and dissolved molecules will not be so crowded as to show irregular behavior. Thus in the case of magmas undergoing molecular flow, Fick's law will be valid at least to within a short distance from contacts and may hold absolutely up to the contact. In the differentiation of a homogeneous magma into consanguineous portions it is hardly supposable that the molecules undergoing transfer are densely crowded. Consanguineous rocks do not differ very greatly in composition, so that no extensive transfer of material is called for. Furthermore, magmas must be regarded as solutions of a series of very similar substances, and it is known that in such cases the solubility of each is diminished by the presence of the others. This was first pointed out by Mr. Nernst and has been confirmed on experimental and theoretical grounds by Dr.

* If v is the quantity of substance in solution per unit volume in Fick's case (or the temperature in Fourier's), if x is the distance measured in the single direction in which diffusion is supposed to take place, and if κ is the diffusivity regarded as constant, then in either problem

$$\frac{dv}{dt} = \kappa \frac{d^2v}{dx^2}.$$

A. A. Noyes.* Thus the solubility of lead chloride is reduced by the presence of other chlorides to something like one-half of its separate solubility. It appears substantially certain therefore that a series of silicates in solution must restrict the solubility of each. Consequently conclusions drawn from the assumption that Fick's hypothesis is exact will be applicable to the process of differentiation.

It is interesting and extremely important to observe that the problem of determining the distribution of a diffusing lava is formally the same as that of finding the distribution of temperature in a cooling globe of large radius. This last is a subject which has become familiar to geologists through Lord Kelvin's application of the results in estimating the age of the earth.

The diffusivity of a substance is inversely proportional to the molecular friction which the molecules or the ions experience. Thus if r_1 and r_2 are the frictional resistances of the ions of an electrolyte, O the osmotic pressure and D the diffusivity, then, as was shown by Nernst:

$$D = \frac{O}{r_1 + r_2}$$

This internal friction is usually known in English as viscosity. The viscosity of liquids so far as is known increases with the pressure to which they are subjected, with the exception of water, which at ordinary temperatures becomes less viscous with increasing pressure. Of course water at temperatures approaching its freezing point is an anomalous liquid. According to Amagat, the anomalous expansion of water ceases at 50° C. and Tammann suggests that the exceptional relation between viscosity and pressure is probably confined to the same limit.

Rate of diffusion.—If two miscible solutions are brought in contact and a time t , measured in seconds, is allowed to elapse, the fluid at a distance of x centimeters from the contact will contain a certain amount of the diffusing fluid per cubic centimeter, which may be called s . One of the fluids may be supposed kept at constant composition, as in the case of a solid dissolving in a solvent. Then this same concentration s will be found at nx centimeters after the lapse of n^2t seconds. For example, if common salt is brought in contact with water, the water in immediate contact with the salt will soon become saturated. At the distance of 1^{cm} the solution will be half saturated in about one day; at 2^{cm} it will be semi-saturated in four days and at 100^{cm} in $100^2 = 10,000$ days; at 100 meters the

* Zeitsch. phys. Chemie, vol. ix, 1892, p. 623.

water would contain half as much salt as it could dissolve after $10,000 \times 10,000$ days, some 270,000 years.

It is because of these relations that stirring is so efficacious in assisting solution. If a mass of fluid consisting of equal but separate parts of concentrated brine and water were so stirred that the streaks of each were not more than a couple of centimeters in thickness, a day would complete by diffusion a homogeneity which unassisted diffusion could accomplish only after hundreds of thousands of years.

Now salt (in common with other haloids) is a highly diffusive substance. The oxygen salts, such as the sulphates of zinc, copper and magnesium, are more analogous to the silicates which compose magmas. Of these the magnesian salt diffuses fastest and the zinc salt the slowest. As an illustration, the copper salt may be taken. Its diffusivity has been determined by Mr. T. Schuhmeister at 0.00000243 in square centimeters per second. With this datum it is easy to compute the distribution of the diffusing salt at any time.* The following table is computed for one year and for 1000 years from the commencement of diffusion. The distances are measured in centimeters from the contact, and under "saturation" the quantity of sulphate of copper per unit volume of the substance at corresponding distance is given, the strength of the original undiffused sulphate solution being taken as unity:

| Saturation. | Distance in centimeters; time 1 year. | Distance in meters; time 1000 years. |
|-------------|---|--|
| 1.000 | 0. | 0. |
| .750 | 3.96 ^{cm} | 1.25 ^m |
| .500 | 8.36 | 2.77 |
| .250 | 14.24 | 4.50 |
| .100 | 20.37 | 6.44 |
| .050 | 24.45 | 7.73 |
| .025 | 27.76 | 8.78 |
| .010 | 31.91 | 10.19 |
| .005 | 35.04 | 11.08 |

Diffusion of CuSO_4 at the end of 1 year and of 1000 years [or of hypothetical lava at the end of 50 times these periods; or of heat in underground strata after $2^h 8^m$ and of 89 days].

The last number in this table shows only half of 1 per cent of the original solution and this may be taken as the limit of sensible diffusion. It is easy to derive from this table the figures for any other time. Thus after a hundred years the distances answering to the given saturations will be ten times as great; sensible diffusion will cease at 350^{cm} and semi-saturation

* For the necessary information on this computation see Kelvin's Math. and Phys. Papers, vol. iii, p. 432, or Brit. Assoc. Rep., 1888.

will occur at 84^{cm} from the original contact. After 10,000 years the distances just stated will each be multiplied by 10. At the expiration of a million years the water would be just sensibly discolored by bluestone at 350^m and semi-saturation would have reached to a distance of some 84^m.

Viscosity of lavas.—Lavas are assuredly far less diffusible and far more viscous substances than sulphate of copper solution.* There is no means of determining with any approach to accuracy what the diffusivity of lava really is, but there is some reason to think that the viscosity of even the most fluid lavas is more than 50 times as great as that of water.† If one

* It is of course needless to call attention to the difference between fusibility and fluidity. A mass may be easily fusible but very viscous when fused, or it may fuse with great difficulty and when fused be very fluid. That a lava is **very** fluid does not indicate that it is considerably superheated. Water at 0° C. is sensibly as mobile as at 100°, though refined experiments reveal a difference.

† The viscosity of lavas is evinced by the slowness with which lava streams advance. Thus in the Kilauea eruption of 1840 the lava flowed eleven miles down a declivity of 1244 feet in two days, yet according to Wilkes and Dana (*Characteristics of Volcanoes*, 1890, p. 63) in this case the stream was fed from several fissures along its whole course instead of being an overflow from a single opening. The heat of the stream must have been pretty well maintained by such accessions. The average rate of flow of this lava down a 2 per cent slope was about $\frac{1}{4}$ mile per hour or 22 feet per minute. Now water in a stream of such a cross section on such a grade would flow at about 6 miles per hour or about 24 times as fast. Since lava is about 2.5 times as dense as water, these data roughly indicate for the kinetic viscosity 2.5×24 or 60 times the viscosity of water.

In the case of gases Maxwell shows that the diffusivity of mass is 1.5435 the kinetic viscosity (*Theory of Heat*, chapter 22) and that the ratio of diffusivity to viscosity in the case of liquids is much smaller than in gases. Hence it seems safe to assume the diffusivity of lava as not more than $\frac{1}{50}$ of that of a solution like that of bluestone.

In the more recent literature I have not met with investigations which throw light on the relations between diffusivity and viscosity. The resistance which molecules, atoms or ions meet when undergoing diffusion Ostwald illustrates by the slow subsidence of pulverized solids in air (*Lehrbuch der Allgem. Chemie*, vol. i. 1891, p. 698). This slowness is due, at least in part, to the viscosity of the air, and Stokes in 1851 showed that the resistance of spherical particles is proportional to the radius. As has been mentioned, viscosity is a resistance due to the diffusion of momentum. That viscosity impedes diffusion of matter appears evident, for example, from the behavior of sealing wax, which is an ultra-viscous fluid. Sticks of wax of different colors which have become adherent during hot weather do not diffuse into one another sensibly even after months of contact. On the other hand diffusion of crystalloids takes place in quasi-solid gelatine jelly at the same rate as in a fluid (Graham). This, however, I take to be not comparable to the action of a viscous fluid, but to the behavior of a colloid septum such as bladder, but of great thickness. The jelly seems to me to have a structure similar to a sponge of very fine grain preventing convection but not the diffusion of crystalloids. Colloids do not diffuse in such a jelly.

In discussing lavas it should not be forgotten that high temperature accelerates diffusion, which adds to the difficulty of making any estimate of the diffusivity of rock magmas.

In choosing as an illustration of diffusion an hypothetical magma with $\frac{1}{50}$ of the diffusivity of bluestone, I have been guided in part by observation on lavas. Lavas with this diffusivity mingled in thin layers, like banded rhyolite, would diffuse into approximate uniformity in a few hours. No one can doubt that the rhyolitic bands have been in contact for at least a few hours in the fluid state and that they must, therefore, be less diffusible than my hypothetical lava. Similar banding is not infrequent in andesites though it is less common than in rhyolite.

supposes the diffusivity of such a lava to be $\frac{1}{50}$ that of sulphate of copper solution, then the time needful to give a certain saturation at a certain point will be 50 times as great. It would take 50 years instead of 1 to establish the conditions given in the second column of the table. A million years is $20,000 \times 50$ or $141^2 \times 50$ and consequently in this vast period sensible impregnation of the lava would have extended to only about 49^m from contact (i. e. $141 \times 35^{\text{cm}}$) and semi-saturation to some 12^m.

It may seem to some readers that I have exaggerated the viscosity of lava. Certainly literature contains some accounts of lavas said to "run like water," but I have been able to find no approximately precise data indicating such fluidity. That most lava streams, those of Vesuvius, for example, advance even on steep declivities at a small fraction of a mile an hour is certain. It will be seen, however, that the arguments of this paper would not be essentially changed if lava were supposed no more viscous than a bluestone solution. But it may also be asked why even greater fluidity may not be assumed in lavas prior to eruption, a fluidity sufficient to allow of segregation in a moderate time. There seem to me abundant grounds for refusing assent to such an assumption. Hypogeal magmas must be under great pressure and they must be close to their melting points; for if they were considerably superheated the surrounding rock masses would melt and the temperature would fall to the melting point. To bring about considerable superheating would be almost as difficult as to boil water in a vessel of ice. The less viscous the magma the more difficult would superheating be. Now liquids which, like lava, condense in solidifying are most viscous at the melting point, and pressure increases their viscosity. Hence hypogeal lavas must be more viscous than they are when they reach the surface. The relief of pressure is equivalent to superheating. It is, therefore, irrational to assume that lavas prior to eruption are at all more fluid than they are at eruption. All indications point to the opposite conclusion.

These illustrations show that diffusion of fluids, particularly viscous ones, is an excessively slow process. It is instructive to compare its rate with that of the diffusion of heat. According to Lord Kelvin, the time required for the diffusion of common salt in water to be represented by a given curve is more than 870 times as long as that needful to diffuse heat through underground strata in such a way as to be represented by the same curve.* Copper sulphate requires five times as much time

* The diffusivity of heat in underground strata has an average value of 0.01. In Lord Kelvin's article on heat, *Enc. Brit.*, 9th ed., vol. XI, p. 582, Table B (auto-graph issue), the time required for the diffusion of heat in underground strata should be given as 3,170,000 years instead of as $\frac{1}{10}$ of this period.

as salt and the hypothetical lava 50 times as much as the sulphate. Diffusion of matter in the lava, therefore, takes over 200,000 times as long as the diffusion of heat in solid rock at ordinary temperatures. Even if melted lava conducts heat many thousand times worse than solid rock, so that the conductivity of the fluid might be neglected, the temperature in an unequally heated mass of melted lava would be sensibly equalized by the conduction of the solid walls of the reservoir before any tendency to molecular flow which difference of temperature might have induced would have had time to produce sensible effects.

Now in any case of the segregation of homogeneous, miscible, fluid magmas by molecular flow, the available osmotic force is only the difference between two osmotic forces, and the transfer of a given quantity of matter to a given distance will be much slower than in simple diffusion. Hence, so far as I can see, a mass of lava of volume, say 1 cubic kilometer, would not have had time to segregate into distinctly different rocks by molecular flow if it had been kept melted since the close of the Archæan, even if the temperature of the top could have been kept sensibly above the temperature of the bottom. But it is very difficult to imagine how a mass of lava could be more highly heated at the top than at the bottom, since in general temperature increases with depth. If the bottom were more highly heated than the top, of course convection currents would be set up and those would effectually prevent any segregation on Sorét's method. I do not think this method should be invoked in explanation of rock differences unless it can be shown how heating from the top can occur.

No such difficulties present themselves in such cases as that of the growth of a crystal. A supersaturated solution of a given substance cannot exist in immediate contact with the solid form of the same substance, but a solution may be supersaturated at a very short distance from the solid mass. In cases of crystallization there is thus an osmotic pressure-difference directed toward the growing crystal, and molecular flow results. The molecular flow attending the formation of phenocrysts is usually confined to distances of a few millimeters, or at most a few centimeters, and is clearly a process involving no unreasonable amount of time. Similarly the formation of aureoles of diffusion around blebs to distances of a few centimeters is not a very lengthened process. Thus if such a bleb had the properties of the hypothetical lava discussed above, an aureole 5^{cm} in depth might form around it in about a year, and sensible diffusion would extend to a distance of 1^{mm} in the comparatively short period of 3½ hours.

Convection unavoidable.—It has been shown above that

segregation of magmas by the method of Ludwig and Soret would occupy a stupendous time even if a mass of melted lava could be kept free from convection currents. This freedom, however, could only be secured by permanent, regular decrease of temperature from the upper surface of the magma downwards. In any fluid of only moderate viscosity even a very small rise of temperature at the bottom would cause convection currents which in a day would undo the segregation it had taken thousands of years to accomplish by Soret's method. Lavas of very great viscosity would also mingle by convection far more rapidly than the most diffusible solutions could segregate through differences of temperature. Mingling again might occur in the absence of bottom-heating by any mechanical disturbance of surrounding rock masses.

That in general the temperature of the globe increases with depth is perhaps the best established generalization of geology. Hence even if it be granted for the sake of argument that in some particular locality the temperature decreases with depth, it is clear that such a thermal distribution is a case of unstable equilibrium. It can, therefore, only be temporary and it would surely be a strange exception were such an abnormal distribution of temperature to last for 1000 years. Yet in that time no segregation worth mentioning as an origin of rock differences could occur. The normal condition of a hypogeal molten magma must be that in which temperature increases with depth and in which convection effectually precludes any process of segregation by molecular flow.

Immiscible fluids.—Another method of segregation, which is quite distinct from that discussed above, depends upon changes in the mutual solubility of fluids. Some fluids which at certain temperatures mingle in all proportions dissolve one another only in certain proportions at other temperatures. Thus benzol and acetic acid mix without limit at 15°, but below this temperature separate out into two layers, one of which contains nearly twice as much acetic acid as the other. So, too, phenol and water mingle freely above 69°, but not below this temperature; and there are many similar instances. The phenomena were studied by Mr. Alexejew, who concluded that in all cases where the solutions do not react chemically upon one another they become miscible above a certain temperature.*

Though Mr. Alexejew studied some of the physical relations of solutions of fluids in fluids, he did not determine whether the passage from complete to partial miscibility is accompanied by expansion or contraction. This step, however, has been taken by Mr. Herman Pfeiffer in Prof. Ostwald's laboratory. He finds that this change is accompanied by a sudden sharp

* Wied. Ann., vol. xxviii, 1886, p. 327.

contraction of volume.* It appears to follow of necessity that at the temperature of complete miscibility under a given pressure an increase of pressure would resolve the homogeneous fluid into immiscible portions.

In close relation to this separation of a homogeneous fluid into different layers is the precipitation of a solid from a fluid. The process of solution of a solid is one involving the absorption of heat, and in general the solubility of solids increases with the temperature. Anomalous cases appear to be referable to changes in molecular aggregation, the formation of hydrates and like causes. The influence of pressure on the solubility of solids was first carefully investigated by Dr. Sorby†, and Mr. F. Braun‡ has more recently made a very thorough study of the subject. Experiments have naturally dealt almost exclusively with aqueous solutions at ordinary temperatures, and it must be borne in mind that as water is a fluid of very exceptional properties the direct results of experiments on solutions in water are not immediately applicable to other fluids such as lavas. Most substances dissolve in water under contraction of volume and only about half a dozen compounds are known which undergo dilatation during solution. Now when contraction takes place increase of pressure will and does assist solution. If contraction were a universal concomitant of solution the interior of the earth would be fluid. But Mr. Braun gives apparently sound reasons for believing that even in aqueous solutions under high pressure and temperature, dilatation and not contraction would attend solution. The investigations of Prof. Carl Barus§ and others and some observations of mine on dikes|| show that lavas contract in solidifying. The frequent corrosion of phenocrysts is seemingly due to increase of solubility attending relief of pressure. Thus for magmas it appears that increase of pressure promotes precipitation of solids as well as segregation into distinct fluids.

Segregation by immiscibility.—In fluids which, though originally homogeneous, tend to break up into two or more immiscible parts, two distinguishable modes of separation may be followed. As the temperature of separation is approached, the walls of the vessel being cooler than the fluid, any component about to separate out will separate to some extent on the containing walls much as frost or dew forms on good conductors. It does not appear that any large part of a large mass of even a moderately viscous fluid could be segregated in this way, for the process involves molecular flow from the interior of the fluid.

* Zeitschr. phys. Chemie, vol. ix, 1892, p. 469.

† Proc. R. S., vol. xii, 1863, p. 538.

‡ Wied. Ann., vol. xxx, 1887, p. 250.

§ This Journal, vol. xliii, 1892, p. 56; vol. xlv, 1893, p. 1.

|| North Amer. Rev., April, 1893.

Thus in a spherical mass of 100^m radius, if half of a component were thus to be deposited on the walls, a portion of this deposit would have traversed a distance of nearly 21^m by molecular flow, which would take thousands of years even in the case of a solution of bluestone in water.

If the separating fluid does not condense on the sides of the enclosing cavity, it must condense somewhat like fog in the mass of the fluid. Now in a very fluid mass, like water, the larger drops of such a fluid will rise or sink more rapidly than the smaller ones, coalescence will occur and the lighter fluid may separate out in a layer. But even in the case of a foreign material suspended in air viscosity greatly delays such separation. The clouds are substantially aggregates of small water drops which, because of the viscosity of the air, fall so slowly that the slightest current sweeps them along. So, too, dust remains suspended in the atmosphere because air is viscous.* In fluids such as lava it scarcely seems credible that any extensive separation of a precipitated immiscible liquid should occur. It may be that spherulites and perhaps some phenocrysts are crystallized from drops of such liquids. However this may be, it is certain that many of the phenocrysts form before eruption and remain suspended in the magma in spite of densities differing considerably from that of the medium.† Thus even in the process of the separation of fluids into immiscible or partially miscible fractions I can see no adequate explanation of rock segregation. Furthermore, if, as seems to follow from the law of fusion, magmas are not heated much above the melting point, there is but a small range of temperature within which such separations could occur and they would be correspondingly rare.

Heterogeneity of the earth.—If the physical theory of solution fails to account for rock segregation, two alternatives are left. Either segregation takes place in accordance with some principle of physics as yet undiscovered (*ignotum per ignotius*), or the facts which have led to the hypothesis of segregation are capable of a different interpretation not at variance with the known properties of matter and compatible with reasonable limits to geological time.

So far as I know, all geologists and astronomers are in unison

* The viscosity of media is probably only one of the influences affecting the subsidence of disseminated fluid or solid particles

† It is well known that phenocrysts in fresh surface-flows are often bent and even broken. Sometimes black borders have formed about hornblendes thus fractured. Such fractures must have happened during eruption. The lithologist will not require to be reminded that phenocrysts of augite and of amphibole with a density of say 3.25 are often of about the same size as those of feldspar with a density of say 2.65, yet there is as a rule no tendency to the separation of the lighter and heavier phenocrysts into distinct layers.

in the belief that the earth has been fluid, not indeed at any one time from center to its present surface, but at least to a great depth from the temporary surface of the growing globe. Yet the earth is clearly not a homogeneous mass, nor is it a system of concentric shells, each homogeneous. The mere fact that one hemisphere is almost entirely covered by water shows that the globe is of greater density below this great ocean than beneath the opposite continental surface. Were the shells homogeneous no continents could protrude above the sea. Were the earth of uniform composition no mountain ranges could stand above the plains. Were the material below the plains uniformly distributed there could be no anomalies of gravity such as occur near Moscow, in Kansas, and elsewhere. The distribution of feldspars in the western part of this continent shows lack of homogeneity, for on the Pacific slope potash feldspars are marvelously rare. No trachyte and extremely little typical granite is known from the Wahsatch range to the Pacific ocean. The distribution of metallic ores shows heterogeneity. Much more than 90 per cent of the known tin ores of the world lie in a belt stretching from the straits of Malacca to Tasmania. There has been deposition of mercurial ores in this belt also; but their quantity is insignificant. A belt of quicksilver deposits extends from British Columbia to Chili. In this belt there is tinstone at many points, but the total product of tin on this belt is scarcely worth mentioning. I can only infer from these facts that quicksilver is an extremely subordinate component of the earth in the Australasian region and that the globe contains little tin along the Cordilleran belt. It is needless to observe that in almost any small area the rocks show marked variations or that two hand specimens from the same locality are rarely indistinguishable. Deserving of special mention, however, are the striped rhyolites, the banded gabbros studied by Sir Archibald Geikie and Mr. Teall, and the ribbon gneisses so abundant, for example, in the southern Appalachians. The rhyolite at least has been fluid, and most geologists consider gabbroitic and granitic magmas as fluids. The diffusion exhibited in these cases is slight and sometimes hardly perceptible to the naked eye, yet it is scarcely supposable that these bands were not in contact for days at least in their mobile state. Now my hypothetical lava would diffuse to the depth of a millimeter in three or four hours. Hence these sharply banded rocks must be much less diffusible than my assumed lava and the diffusivity of the granular rocks and their fluidity would scarcely exceed zero.* Thus from the surface of the globe to its minutest

* Banding such as is found in gneiss and rhyolite could not result directly from segregation on Soret's methods or by difference of pressure, for these processes

portions there are clear indications of heterogeneity, notwithstanding that similar rocks and similar series of rocks occur in widely dispersed localities.

Is there any valid indication that uniformity ever reigned? It used to be thought that the Archæan rocks were uniform, but it is well known now that they are not so. The early eruptions and intrusions seem quite as diverse as the modern ones, excepting so far as original differences are masked by metamorphism. The theory of the permanence of continental areas has many very strong supporters, and that land areas have existed since the Cambrian seems certain. The mountain system of the world in its larger features appears to have been outlined during the Archæan, and there are observations indicating a highly accentuated topography even in those days. Were the indications of heterogeneous composition confined to the immediate neighborhood of the earth's surface, it might be maintained that these inequalities had been brought about since consolidation, but everything tends to show that only the shell of the earth next to the surface and a few miles in depth partake sensibly in orogenic movements, while several of the evidences of heterogeneity point to inequalities at great depth.

Uniformity unattainable.—If the earth condensed from a nebulous ring, it is fairly inconceivable that the successive shells of the growing mass should each have been uniform in composition; and if the origin of the earth is a ring thrown off from the sun, the coalescence of this ring to a globe cannot have resulted immediately in uniform distribution of matter. The sun spots show that the sun is not even yet an aggregate of shells each uniform in composition. The exterior layer of the globe must have retained such fluidity as it possessed for a very long time, and must have passed by insensible gradations through every temperature between the initial one and that of consolidation. Had the various component portions of this layer been of large size, of low viscosity, and not miscible with one another, they would have arranged themselves in the order of density quite irrespective of chemical composition. If the masses were viscous, however, nothing like a perfect separation according to density could occur in

can lead only to very gradual transitions. Banding might conceivably result from such a segregation followed by active stirring, but only on condition that stirring was immediately followed by solidification, for otherwise diffusion would restore homogeneity. Separation of a magma into immiscible portions followed by active stirring might also produce banding, but again only on condition of immediate consolidation, since otherwise separation into two layers would again take place and much more rapidly than at first.

Miscible substances in contact which do not diffuse at a finite rate can have no sensible vapor tension and must be solids or ultra viscous fluids. Immiscible fluids must have a perfectly sharp contact like that between a lead button in an assayer's crucible and the enveloping slag.

this way and only a rude approximation to regularity would be attained.

If the melted masses were partially or wholly miscible, much the same arrangement would take place at first because diffusion on any large scale is at best a relatively slow process. Then diffusion and convection would come in play, tending to equalize the composition.

On the other hand, unless the originally heterogeneous masses had very different properties from those of remelted rocks, whether of Algonkian or modern time, they cannot have diffused on any large scale, and uniformity along equipotential surfaces cannot have been attained even if fifty million years were allowed for the process, unless the convection currents were so powerful and universal as to break up the original masses into streaks of a few meters in width. I see no cause for convection so active as this. In the nebulous state the material of the earth must have assumed some approach to convective equilibrium of temperature, and though here and there the solidifying globe may have been affected by disturbances of frightful intensity, analogous to sun spots, a general diversity of temperature sufficient to stir the whole or most of the melted layer into uniformity seems utterly improbable.

What is known of the properties of matter seems to me to point to the hypothesis that the material of the earth is rudely arranged by density irrespective of chemical composition, the different masses mingling for a few meters or scores of meters along their common boundaries, this structure being due to original heterogeneity. If segregation took place at all, prior to the consolidation of such a globe, this process would be limited to particular masses and would tend to still greater heterogeneity.

Hypogeal refusion.—Consider now the effect of the refusion of any portion of the earth's mass. Unless the temperature of the magma were raised essentially above the initial temperature of the molten globe, or unless it were melted at a very different pressure, the magma would simply be restored to the condition in which it existed before the primal consolidation. There is no indication that lavas prior to eruption are really raised to temperatures greatly above that of fusion, for almost all of them bring solid phenocrysts to the surface, nor is it easy to see how they could be heated much above the melting point, for so long as there was unfused material of a similar character in the neighborhood of the subterranean mass undergoing fusion, any heat increment would of course melt more rock instead of raising the temperature of that already fused. Thus it is substantially certain that in the molten globe

a given magma passed very gradually through the temperature at which it has more recently been remelted. As for the pressure, it seems possible that under continental areas a given fusing subterranean mass may exist under a somewhat smaller load than that to which it was subjected at primal consolidation, for the general tendency of continents is to upheaval and degradation by erosion. If this change of pressure is of any consequence at all, it will tend to make the refusing mass more fusible and more miscible.

If now the mass were both homogeneous and in molecular equilibrium before the primal consolidation, it may be in equilibrium after refusion. If the pressure is smaller than the original one, this difference would have no tendency to promote segregation. If by some almost inconceivable coincidence, the upper portion of the refused mass were heated to a higher temperature than the lower part, this temperature would be equalized by conduction through the walls, if not through the liquid, before any sensible segregation could occur.

If the mass were heterogeneous in consequence of primal segregation, fusion would again tend to restore molecular equilibrium and the only chance of a new segregation would lie in the possible difference between primitive and ultimate pressure, which, if positive, would tend to mixture rather than to separation.

If the mass were heterogeneous because the primal fusion had not continued long enough to bring about homogeneity, refusion would be accompanied by a tendency to continue the process of molecular flow and to decrease the heterogeneity of the mass; but even if the refused mass were kept molten for a million years, this tendency would probably have only insignificant results.

Mixture by eruption.—Little or nothing is known of the process of refusion of subterranean masses to eruptive magmas. Supposing a mass which is fused and near its melting point to remain in its subterranean reservoir, it must in general receive or lose heat. In the latter case it will reconsolidate, in the former the mass of melted material will increase. In the case of rocks, fusion is accompanied by expansion and the magma must have more space than it occupied in a solid condition. Any elastic strains in surrounding masses will also tend to expel it and it would seem to me most probable that magmas are expelled as soon as the mass of melted material had increased to a certain limit dependent upon local conditions. If so, there must be little time for the fulfillment on a large scale of a process so slow as molecular flow. Doubtless fusion may be confined to a nearly homogeneous portion of the earth's lithoid shell. If the hypothesis explained above of

primitive, unmingled, unsegregated masses is correct, a good many of these must have the composition of augite-andesite; for this as well as several other simple rock types has issued at most distant points with almost constant characteristics. Fusion may, however, also affect two or more diverse masses and then eruption tends to mingle them. Ejection through pipes or fissures must indeed be a most efficient stirring process, and since relief of pressure is accompanied by depression of the melting point, different magmas thus ejected are superheated and may mingle to an observable extent by diffusion before they finally consolidate. In such cases one would probably find two (or more) rock types accompanied by mixtures of variable composition. Again, a fissure through which different types were extruded successively or in mixture might at the close of the eruption be filled with a single type or with a mixture. If such a mixture were at all intimate, diffusion would mask the original differences and the case would be one of apparent transition.*

Possibly some of the observed occurrences which have led to the hypothesis of differentiation are really of this character, for I think it has been shown in the foregoing pages both that transitions can be explained on the hypothesis of primitive heterogeneity and that the explanation of differentiation itself presents formidable difficulties. I do not see why it should be necessary or desirable to assume that in the early history of the globe the vast shell from which eruptions issue was reduced to substantial uniformity. Experience affords no analogy in support of such an assumption nor has any theory been propounded which will account for it.

If primitive heterogeneity is still an important feature in the earth's structure, and if unmingled magmas represent primitive differences, the labors of lithologists would naturally be directed to detecting these original types. These would probably be recognizable by their wide distribution and constant character. Then areas of rapid variation would be regarded as representing mere mixtures and it might be possible to reduce instead of increasing the number of rock species.

Abstract.—All known processes by which the segregation or differentiation of a fluid magma could take place involve

* The order of mixture and extrusion would seem to depend on many circumstances, among others on the shape of the subterranean reservoirs. If this were a cone with its vertex nearest the surface, the disposition of the ejecta would be very different from that which would be observed if the reservoir were a flattened lens with its edge horizontal and a vent on one surface. If each eruption represents a separate melting, still other dispositions will result. It appears to me anything but remarkable that different observers find eruptions in different areas taking different orders. Gradual solidification from fissure walls of dike magmas circulating by convection may lead to preponderance of less fusible ingredients near the edges of a solid dike.

molecular flow. This is demonstrably an excessively slow process excepting for distances not exceeding a few centimeters. Soret's method of segregation, even if it were not too slow, seems inapplicable because it involves a temperature unaccountably decreasing with depth. The normal variation of temperature, an increase with distance from the surface, would be fatal to such segregation. The least objectionable method of segregation would be the separation of a magma into immiscible fractions; but this seems to involve a superheated, very fluid magma, while the law of fusion and the distribution of phenocrysts in rocks indicate that magmas prior to eruption are not superheated to any considerable extent and are very viscous.

The homogeneity of vast subterranean masses called for by the hypothesis of differentiation is unproved and improbable. The differences between well-defined rock types are more probably due to original and persistent heterogeneity in the composition of the globe. Hypogeal fusion and eruption tend rather to mingling than to segregation, and transitional rock varieties are not improbably mere fortuitous mixtures of the diverse primitive, relatively small masses of which the lithoid shell of the earth was built up.*

Washington, D. C., October, 1896.

*I owe thanks to Dr. Arthur A. Noyes of the Mass. Institute of Technology for kindly examining the manuscript of this paper. Dr. Noyes's reputation as an investigator in osmotic questions gives his approval of my argument great value.

ART. IV.—*On Igneous Rocks from Smyrna and Pergamon*;
by HENRY S. WASHINGTON.

OF the specimens described in the following brief notes those from Mt. Pagos near Smyrna and from Pergamon were collected by the writer in the spring of 1892. Those from the other Smyrna localities were collected by Mr. J. S. Diller in the summers of 1881 and 1882, who most kindly presented them and his notes for use in the preparation of this paper. It may be mentioned, in justice to him, that these form but a small part of those he collected, the rest not being available in time for publication. The writer gladly avails himself of this opportunity of expressing to Mr. Diller his heartiest thanks for his kindness and generosity. It must be premised that these notes are but fragmentary and that their publication seems only justified by the scantiness of our knowledge of the rocks of Asia Minor.

Augite-andesite, Smyrna.—The city of Smyrna lies at the head of a deep gulf in the west coast of Asia Minor and is surrounded on three sides by igneous rocks. To the northwest are the hills of Phocæa, probably of andesites and their tuffs; to the north and northeast the andesitic masses of Yamanlar Dagħ and Mt. Sipylus; and immediately to the south and southwest a ridge of igneous rock formed of the hills of Mt. Pagos, Kara Tash and Giöz Tepé. Since the early descriptions of Hamilton* and Tchihatcheff,† little or nothing has been written on the geology of this region, with the exception of a short paper by vom Rath.‡ Of the rocks of Phocæa and the Sipylus ridge I have no specimens, so that we must confine ourselves to those from the immediate vicinity of Smyrna. From the brief descriptions of vom Rath§ and the notes of Mr. Diller, it seems that the Sipylus rocks are closely similar to those of Mt. Pagos, and Mr. Diller also compares them in places with the “hypersthene-bearing andesite by Assos.”

Mt. Pagos, 185^m high, is the eastern end of a ridge, up the northern and eastern flanks of which the modern city of Smyrna extends, and which formed in antiquity the ancient acropolis or citadel, the summit being still crowned with ruined walls. It is composed of a mass of andesite which, according to Hamilton and Tchihatcheff, has been forced up through underlying beds of Cretaceous (?) limestone. In many places

* W. J. Hamilton: *Researches in Asia Minor*, London, 1842, i, 54; also Hamilton and Strickland, *Trans. Geol. Soc.*, London, ii, 293.

† P. de Tchihatcheff: *Asie Mineure, Géologie*, i, Paris, 1867, pp. 69–73.

‡ Vom Rath: *Sitzber. Niederrh. Ges zu Bonn*, 1882, pp. 16–26.

§ Quoted in Roth, *Geologie*, ii, 326, 1883.

the andesite is overlaid by masses of detritus containing numerous shells, and here and there accumulations of shells are found, principally of oysters and scallops (*murex*); snail shells also abound, which closely resemble the numerous land snails of Greece, so far as I was able to judge. Fragments of pottery, mortar and charcoal are also found in the detritus, and these deposits seemed both to Mr. Diller and myself to be in reality "kitchen-middens" rather than deposits from water or old beaches. Mr. Diller's notes, however, show that along the Meles River the andesite is overlaid by soft travertine-like limestone, apparently a lacustrine deposit. In places also andesitic conglomerates were observed.

The general mass, however, is very compact and shows, especially toward the west, a beautifully banded structure, the bands being red and black. The greater part of the mass visible is reddish, the color being due, as we shall see, to decomposition. The freshest rock has a dark gray groundmass, carrying numerous phenocrysts of feldspar and augite and fewer of biotite. Its texture is harsh and in cavities are found small crystals of biotite and acicular hornblende, with globular masses of a zeolite which von Rath regards as a natrolite. Fine mammillary hyalite is also abundant. The specific gravity of a fresh gray piece was found to be 2.640 at 17° C.

Under the microscope the rock is seen to be composed of plagioclase, diopside and biotite, with accessory magnetite, apatite and zircon, lying in a glass base. Neither hypersthene, hornblende, olivine nor quartz was seen in any of the specimens. The structure is eminently the vitrophyric of Rosenbusch and is well shown in fig. 4 of *Tafel v* of his *Mikroskopische Physiographie*, vol. ii.

The plagioclase phenocrysts are often well shaped, but in many cases fragmentary. They are clear and carry only few inclusions of glass, apatite and zircon. Zonal structure is common, the interior being, as usual, the more basic. Nearly all show well-developed twinning lamellæ according to the albite law, and here and there pericline twinning is seen. Examination of sections on $b(010)$ by Michel Lévy's method* showed extinction angles of 20° and 25° on each side of the twinning plane, indicating a labradorite of the composition Ab_1An_1 , or somewhat more basic. The few feldspar phenocrysts that showed no lamellæ could not be identified with certainty as orthoclase. The diopside phenocrysts are often well-shaped, though fragments occur. They are almost colorless and clear, and carry only few inclusions of brown glass and magnetite. Some twinning parallel to $a(100)$ is seen, but zonal structure is uncommon. Biotite phenocrysts, in stout hexagonal prisms,

* Michel Lévy: *Détermination des Feldspaths*, Paris, 1894.

are not as common as diopside. They are deep brown, strongly pleochroic, and basal sections show a slight dispersion of the axes parallel to $b(010)$. They are quite fresh and only slightly altered on the edges to a narrow opacitic border, with rounded angles.

The groundmass in general is typically hyalopilitic, the microlites being mostly of labradorite, with fewer of what seems to be orthoclase, some small colorless diopside prisms, many magnetite grains, and a few small crystals of apatite and zircon. These generally show flow-structure. The glass base is usually colorless, though sometimes light brown.

The preceding description applies especially to the fresh gray specimens. The red ones show much the same features, the differences being due to decomposition. Thus in these the augites are colored red or black on the edges, the biotites are a dark red brown, and the groundmass is much decomposed with limonitic products very abundant.

An analysis by the writer of a typical, fresh, dark gray specimen from near the top of Mt. Pagos is inserted here. Its sp. gr. is 2.640 at 17° C.

| | |
|--------------------------------------|-------|
| SiO ₂ | 60.68 |
| Al ₂ O ₃ | 16.19 |
| Fe ₂ O ₃ | 5.37 |
| FeO | 1.58 |
| MgO | 2.96 |
| CaO | 5.88 |
| Na ₂ O | 3.11 |
| K ₂ O | 3.95 |
| H ₂ O | 0.98 |

100.70

It is high in silica and alkalies for an andesite and with rather low alumina. The potash is considerably higher than soda, which would account for the presence of some orthoclase in the groundmass, since biotite is not very abundant, though part of it may belong to the glass base. On account of the vitreous character of the rock it is scarcely practicable to calculate from the analysis a possible mineralogical composition. There is, however, more SiO₂ than enough to satisfy all the other constituents, even assuming that all the K₂O is in orthoclase, which, of course, is not the case; so that quartz would have separated out if the rock had been formed under conditions allowing of a holocrystalline development. On this account the rock might be properly called a dacite.

The rocks of Kara Tash (Black Rock) 2^{km} west of Smyrna, three specimens of which were sent me by Mr. Diller, differ

considerably from those just described. Rosenbusch* describes rocks from this locality as biotite-hypersthene-andesite. I was unable to find any hypersthene in the specimens examined, and the microphotograph he gives resembles very much my sections of the Pagos rocks, and is of a totally different character from all of those of the Kara Tash rocks sent by Mr. Diller, so that it seems probable that the locality of his specimen is incorrectly given.

The Kara Tash rocks are all very dark and compact, showing numerous small glassy feldspars, and a few augite and biotite phenocrysts in a very dark brown or black, highly vitreous groundmass. Some evidences of flow-structure are seen in the hand specimen and are even more marked in the mass, judging from Mr. Diller's notes.

Under the microscope the very well-shaped feldspar phenocrysts are seen to be of labradorite a trifle more basic than Ab, An_1 . They are clear and fresh and show, almost without exception, twinning lamellæ, while zonal structure is frequent. Inclusions are not very abundant, and consist mostly of small spots of dusty brownish glass, with a few apatites. The very pale green diopsides are highly automorphic, perfectly fresh and contain few inclusions. The not very numerous biotites are greenish brown and perfectly fresh, even incipient alteration not being seen. Some large, well-shaped magnetite grains may also be classed among the phenocrysts. The very abundant groundmass is highly vitreous, the glass being quite colorless, and only rare small crystals of augite, feldspar, magnetite and apatite being present. It is chiefly remarkable for the very great abundance of trichites, with which it is thickly crowded. By far the greater part of these are curved, sometimes to a high degree, but some straight ones are seen. Though under low powers they seem opaque, yet high powers show the majority of them to be clear and colorless. Those which seem black and opaque under these conditions probably owe their appearance to their excessive tenuity. What the nature of these minute bodies may be it is impossible to say, since they exert no action on polarized light. The most natural supposition is that they are either diopside or feldspar, and I am inclined to consider them the latter,—probably orthoclase,—basing my opinion on the results of analysis and their rather remote analogies with forms seen elsewhere. Quite well developed flow-structure is observed, which is brought out more prominently by the presence of some narrow dusty gray streaks. The specific gravity was found to be 2.601 at 18° C., the lower figure as compared with that of the Mt. Pagos specimen being chiefly due to the more highly vitreous character.

* Rosenbusch: *Mikr. Phys.*, ii, 890, 1896, also *Taf. v*, fig. 4.

An analysis of the rock of Kara Tash by the writer is given. As will be seen, it resembles in general that of the Mt. Pagos

| | |
|--------------------------------------|--------|
| SiO ₂ | 61.93 |
| Al ₂ O ₃ | 18.47 |
| Fe ₂ O ₃ | 1.93 |
| FcO | 2.23 |
| MgO | 2.66 |
| CaO | 4.31 |
| Na ₂ O | 2.92 |
| K ₂ O | 3.92 |
| H ₂ O | 2.28 |
| | <hr/> |
| | 100.65 |

rock, though silica is somewhat higher and lime a little lower, while alkalies, ferrous oxide and magnesia remain almost exactly the same. Alumina is, however, much higher and ferric oxide lower. Water also is much higher, which may be attributed to the abundant glass.

One of Mr. Diller's specimens from the coast 4^{km} west of Smyrna, between Kara Tash and Giöz Tepé, shows very clearly the red and black banding already mentioned. The black bands resemble the rock just described, while the red look more like the Pagos specimens.

Under the microscope both bands resemble somewhat more the Pagos rock than that of Kara Tash proper, though they differ from either. The phenocrysts, which are of labradorite, diopside and some biotite, are often fragmentary and the finely automorphic crystal boundaries of the Kara Tash phenocrysts are lacking. The red bands show a slight brown coloration of the diopsides and biotites, with limonitic spots here and there. The base is a clear colorless glass, and is quite hyalopilitic through the presence of numerous minute, *straight*, transparent, colorless trichites, with some larger feldspar laths. The groundmass of the black streaks shows in addition large amounts of fine "dust," which gives it a dirty appearance and greatly interferes with its transparency. In this it resembles the dusty streaks of the Kara Tash specimens.

Another specimen from the coast 3^{km} west of Smyrna shows a fine-grained reddish groundmass containing very many glassy feldspars and some small brown spots representing original augite and biotite crystals. In thin section it greatly resembles the red Pagos rocks, and all except the feldspar is much decomposed. The diopsides are all deeply bordered with brown, the biotites are all entirely reduced to brown rusty masses, and the groundmass is much decomposed and dirty.

Another specimen from near the same place shows a dark,

slightly greenish gray, waxy groundmass, with the usual phenocrysts. It contains also an angular enclosure of a fine-grained reddish rock, showing only few phenocrysts of feldspar. This is separated in part from the enclosing rock by a crevice, the walls of which are lined with crystals of prehnite. Seen in thin section, the main rock is seen to be much decomposed, but resembled originally the red bands just described. The labradorite phenocrysts are fresh, but the diopsides and biotites are decomposed as before, though the product is rather darker. The abundant vitreous groundmass is of a brown glass, rather dusty, and the numerous straight trichites are black through decomposition.

The reddish enclosure is so thoroughly decomposed as to render examination very unsatisfactory. It is evidently a volcanic rock, probably more basic than the andesites previously described, and allied to the olivine-free basalts. The only phenocrysts visible in thin section are of colorless diopside, in stout prisms often with pyramidal terminations. These show the usual brown decomposition border. The groundmass is much decomposed in general to an indeterminate dirty mass, with spots of calcite here and there. In parts of the slide, however, it preserves fairly well its original structure—being composed of long slender prisms, or perhaps sections of plates, of feldspar, with interstitial brown glass base. These feldspars show no twinning, and in many cases extinguish parallel to their length, or nearly so, while in others the extinction is oblique at angles up to 26° . We may then suppose them to be of orthoclase or oligoclase, and labradorite. In general they form groups of needles parallel to each other, but in a few cases compose sheaf-like, diverging forms. No evidence of the former presence of olivine or biotite could be made out.

The only specimen of the rock of Giöz Tepé* (Eye Hill) shows a compact, greenish gray groundmass, with brownish feldspars and a few small augites and biotites.

Under the microscope this also is seen to be somewhat decomposed, though in a different manner from the preceding. While the substance of the feldspar phenocrysts is fresh, yet they are traversed by numerous brown dusty cracks, and their glass inclusions are all similarly altered. The few augite phenocrysts present are pale green and quite fresh, without the usual dark borders. The dark green biotites are profoundly decomposed, though there is usually a core of unaltered substance. There are also present many rather long stout prisms of a dull, opaque, brownish, granular decomposition product,

* This is the name as given on Kiepert's Map of Western Asia Minor (Berlin, 1892), and is not an uncommon one in the country. Rosenbusch renders it Yous Tepé.

the original mineral being entirely gone. It may have been augite, or perhaps more probably hypersthene. A few larger patches are reminiscent of magmatically altered hornblende. The groundmass is much decomposed, but not sufficiently so to hide the fact that it is holocrystalline and largely of feldspar, with numerous now rusty remains of long ferromagnesian microlites and laths. Serpentinous patches are also present. It must be noted that the rocks of Giöz (Yous) Tepé are referred by Rosenbusch to biotite-augite-andesites.*

Finally, a specimen from a locality "3^{km} south of Smyrna in the railroad cut where the aqueduct crosses the Meles River," may be briefly mentioned. This resembles the gray rocks of Mt. Pagos, but is rather decomposed. Under the microscope the phenocrysts of plagioclase and augite are rather less abundant, and only few of biotite are to be seen. The groundmass is also gray and thickly sprinkled with dusty grains and microlites, and there is little or no evidence of flow. Greenish andesites are also reported by Diller from this neighborhood, whose color is apparently due to decomposition.

Biotite-dacite, Pergamon.—The hill which formed the acropolis of the ancient Greek city of Pergamon lies 25^{km} east of the coast and some 60 north of Smyrna. It stands at the junction of two small streams which unite here to form the ancient Kaikos. It is 310^m high—the southern end of a long ridge which rises steeply from the surrounding alluvial plain. In structure the hill apparently much resembles Mt. Pagos, but I do not feel competent to discuss this point, as my examination was too cursory.

The rock of which it is composed varies rather more than at Mt. Pagos, being generally a hornblende-free, but sometimes a hornblende-bearing, biotite-dacite, which also carries orthoclase in considerable amount. As the presence of hornblende does not affect the other characters, the varieties may be described together. A few tuff-like masses were also seen.

The rocks of Pergamon have been described by J. Roth† and Lepsius‡. The former briefly notes that sanidine, abundant plagioclase and biotite, and rare green augite, occur in a compact gray groundmass. No augite was seen by either Lepsius or myself and was probably hornblende in reality. The description of Lepsius closely agrees with mine, though he notes no spherulites and speaks of the hornblende and biotite as brown.

Over the greater part of the hill the rock is gray, but in places, as in some of the long slopes and near the Temple of

* Rosenbusch, Mikr. Phys., ii, 889, 1896.

† Roth: Geologie, ii, 248.

‡ Lepsius: Geologie von Attika, Berlin, 1893, 168.

Julia at the north end, it is reddish. It is highly porphyritic, resembling the Pagos rock, the dacites and andesites of Aegina and Methana, and some of our western porphyries. Phenocrysts of feldspar, dark biotite, and fewer of hornblende (when present) are thickly scattered through the fine-grained groundmass, without any evidence of flow structure. The specific gravity of the freshest specimen, which was also that chosen for analysis, was found to be 2.525 at 17° C. It is thus notably lighter than the Smyrna rocks, which is probably to be connected with its higher silica content and more vitreous structure.

When examined in thin section the feldspar phenocrysts are found to be chiefly of plagioclase, with a smaller number of orthoclase. In the former the extinction angles of the twinning lamellæ indicate a labradorite of the composition Ab, An_1 . The sanidines are distinguished by their lack of multiple twinning (even Carlsbad twins being rare), their lower refractive index and their parallel or nearly parallel extinctions. The feldspars are very clear and glassy, and contain only a few inclusions of glass and apatite, with very rarely a crystal of biotite. The biotites are, when fresh, of a slightly brownish olive-green, and show no signs of magmatic alteration. In the reddish specimens they are browner in tone and are somewhat decomposed. The hornblende phenocrysts are well-formed, stout prisms of a dark, olive-green color, pleochroic, and perfectly fresh and unaltered. Augite phenocrysts are wanting entirely.

The groundmass varies considerably in structure. In most specimens it is very abundant and highly vitreous. It is more or less hyalopilitic, but not very thickly so, through the presence of feldspar laths, which are mostly plagioclase, with fewer of orthoclase. In one or two slides small square sections of orthoclase are abundant. Along with the feldspar laths are shreds of biotite and some magnetite grains and apatite needles, but no augite microlites. The glass base is colorless or slightly brown, and darker brown spherulites are often present. These are usually irregular in outline and possess a radiate structure, showing between crossed nicols an ill-defined cross. These spherulites are especially abundant in a specimen from near the great Zeus Altar. Perlitic cracking is also observable in many slides. In a few cases, as near the Temple of Julia and south of the Theatre, the base is microfelsitic and brownish in color, probably due to devitrification through decomposition.

For the accompanying analysis (No. 1) by the writer, the freshest specimen was selected from about halfway up the southeast slope. It is gray and contains considerable hornblende. Lepsius's analysis is added for comparison (No. 2).

| | 1 | 2 |
|--------------------------------------|--------|--------|
| SiO ₂ | 63.17 | 61.93 |
| Al ₂ O ₃ | 17.15 | 16.45 |
| Fe ₂ O ₃ | 2.84 | 4.66 |
| FeO | 1.31 | 0.40 |
| MgO | 2.17 | 2.94 |
| CaO | 4.17 | 4.40 |
| Na ₂ O | 3.08 | 4.03 |
| K ₂ O | 4.19 | 2.20 |
| H ₂ O | 2.51 | 2.50 |
| | <hr/> | <hr/> |
| | 100.59 | 99.51 |
| Sp. gr. | 2.525 | 2.539 |
| | 17° C. | 15° C. |

The analyses resemble in general those of the Smyrna rocks, especially that of the Kara Tash specimens. Silica is, however, considerably higher—so high, indeed, that the name dacite is justified, though no quartz has crystallized out.* Iron oxides, magnesia and lime are all lower than at Smyrna. There is a discrepancy in the quantities of the two oxides of iron in the two analyses, but their total amount is about the same. There is also a discrepancy in the alkali determinations, though here again their total amount is about the same. Lepsius' differ from the others in showing higher soda than potash, which is rather surprising when the abundance of biotite and the presence of orthoclase are considered. The high H₂O is largely to be referred to the abundant glass base, though some of it belongs to the biotite molecule.

General remarks.—It would be of much interest to compare the rocks just described with the other volcanic rocks of western Asia Minor. At the present time, however, we are confronted at the outset of any such inquiry by the insurmountable obstacle of almost total lack of data, i. e. of modern petrographical and chemical descriptions. An examination of the geological map of Tchihatcheff shows that a line of volcanic centers extends along the west coast from Smyrna northward, including the areas of Smyrna, Sipylos, Phocæa, Yund Dag, Pergamon, Dalanlar (Kiepert, Doghanlar), the extensive district of the Troad, and Kapoudagh on the Sea of Marmora. As we have already seen in the case of the Assos rocks (page 41), and as may be inferred from the brief descriptions of Tchihatcheff and Diller† the andesitic rocks of these centers much resemble each other. According to Diller, in the Troad some of them carry hypersthene, and they are associated with

* Cf. Küch: *Vulk. Gest. Republ. Colombia*, Berlin, 1892, 19; also H. S. Washington: *Jour. of Geology*, iii, 21, 1895.

† Diller: *Quart. Jour. Geol. Soc.*, xxxix, 632, 1883.

basalts, nepheline-basalts and rhyolites. There is some evidence of the Troad rocks being on a line extending westward through Mytilene and Samothrace,* where quartz-trachytes, trachytes and basalts occur, to Thessaly, where basalt is found at Persufli.† Since the analyses of the andesitic "basalts" of Mytilene and Persufli offer certain analogies with the rocks of Smyrna and Pergamon, they may be here inserted.

| | 1 | 2 |
|--------------------------------------|--------|--------|
| SiO ₂ | 56.58 | 53.61 |
| TiO ₂ | 0.77 | 0.34 |
| Al ₂ O ₃ | 14.88 | 16.11 |
| Fe ₂ O ₃ | 2.31 | 3.05 |
| FeO | 3.04 | 4.45 |
| MnO | 0.16 | 0.14 |
| MgO | 3.76 | 6.80 |
| CaO | 8.69 | 7.00 |
| BaO | 0.07 | --- |
| Na ₂ O | 3.36 | 3.95 |
| K ₂ O | 2.18 | 3.08 |
| P ₂ O ₅ | 0.15 | --- |
| H ₂ O | 2.12 | 1.65 |
| CO ₂ | 2.32 | --- |
| | 100.39 | 100.18 |

No. 1† is of the Mytilene rock, but I can find no description of it. Lepsius describes the Persufli rock (No. 2) as a quite typical olivine basalt, amygdaloidal, and somewhat decomposed. The interest in these at present chiefly centers in the high alkalis, in which they resemble the rocks above, though soda is slightly higher than potash. The two resemble each other quite closely and the potash is high enough to lead one to infer the presence of orthoclase.

It is of interest also to note that an augite-hornblende-andesite is described by Becke§ from the Island of Chios, which lies west of Smyrna. This is propylitic in habit and is compared by him with the andesites of the Bosphorus.

South of Smyrna no igneous rocks are noted on Tchihatcheff's map till the promontory of Budrum (Halicarnassos) is reached. These, however, as well as the rocks of Kos and Nisyros near by, are, as I have pointed out elsewhere,|| probably connected with the Aegina-Santorini line, the rocks of which show lower alkalis, with soda higher than potash.

* Niedzwiedzki: Tsch. Min. Mitth., 1875, 89.

† Lepsius, op. cit., 169.

‡ Chatard anal., Bull. U. S. G. S., No. 60, 1890, 158.

§ In Teller: Geol. Beob. Insel Chios, Denkschr. Akad. Wiss. Wien, xl, 347, 1880.

|| H. S. Washington: Jour. of Geology, iii, 158, 1895.

ART. V.—*Revision of the Genera of Ledidæ and Nuculidæ of the Atlantic Coast of the United States*; by A. E. VERRILL and KATHARINE J. BUSH.

(Brief Contributions to Zoölogy from the Museum of Yale University, No. L.)

A SOMEWHAT extended study of the series of deep-sea bivalves belonging to these families, dredged off our coast by the U. S. Fish Commission, from 1872 to 1887, has compelled us to revise the known genera and subgenera and to propose several new groups. In view of an unexpected delay in the publication of the report upon these families, which had been completed and fully illustrated, it seemed desirable to publish a brief preliminary account of the classification adopted.

These families are often united by modern malacologists under a single family (*Nuculidæ*), while others regard them as distinct. They are certainly closely related anatomically, as well as by the structure of the shell. Thus all the members of both families have a single pair of simple "foliobranchiate" (or protobranchiate) gills; two pairs of large labial palpi, the outer ones furnished with long extensile labial tentacles; a large muscular foot with an expanded, concave, terminal disk, adapted for rapid motions in jumping and swimming, as well as for creeping; and all have two series of transverse teeth on the hinge-margin. The peculiar structures of foot and gills appear together elsewhere only in the family *Solemyidæ*, which is evidently a related group, though it lacks hinge teeth. As these three families have gills of a peculiar and simple structure, each one consisting of two rows of flat lamellæ, attached to a single stem, they have recently been regarded as forming a special order (*Protobranchiata*).

This group is of special interest because of its great antiquity. Large numbers of fossil forms, very closely allied to existing genera and species, occur even in Silurian and Devonian formations.

Thus the common living genera *Nucula* and *Leda* are represented by numerous Devonian species, many of which cannot be separated from the recent forms, even as subgenera, by any tangible characters. Other species of the same age, referred to *Palæoneilo*, agree in nearly all essential characters with the living genus *Tindaria*. These fossil shells are generally larger and stronger than the corresponding living species. Many palæozoic genera which are now extinct were as highly organized and as much specialized as their living allies.

The thin-shelled, strongly siphonate genera, such as *Yoldia*, *Yoldiella*, etc., do not appear so early in geological time and

may be regarded as more modern specializations of the Leda-like forms. They are also the forms that swim and jump with the greatest activity. Therefore the thin and light character of their shells may be regarded as having been secondarily acquired, partly in consequence of their active movements, in which a heavy shell would be disadvantageous, and partly because the development of long siphons enables them to live concealed, much of the time, beneath the surface of the soft mud in which they generally live. In *Solemya* the shell is still lighter and thinner, in accordance with more developed swimming habits, combined with burrowing when at rest. Such forms as *Nucula* and *Tindaria*, which have no siphon tubes, must live at or near the surface of the mud over which they creep with their large expanded pedal disk. (Fig. 15.) These have for their protection comparatively solid shells, similar to those of palæozoic species, in form, texture, and sculpture.

The family Nuculidæ differs from Lediæ mainly in having no siphon tubes, the mantle edges being completely disunited. The Lediæ are remarkable for the great variations in the structure of the hinge-teeth, ligament, cartilage, and mantle, as well as in the form of the shell. The pallial sinus may be wanting or well-developed. Some genera have long united siphons (*Yoldia*); some have shorter ones, more or less separated (*Leda*); while in *Tindaria* there is no true siphon, but only an efferent orifice differentiated. The ligament may be wholly external, as in *Malletia*, *Tindaria*, etc., or it may be rudimentary and replaced by an internal cartilage or "resilium"; or both may coexist in varying degrees of development and degeneration. The hinge-teeth may be very numerous and regularly v-shaped, in each series, or they may be comparatively few and irregular, sometimes becoming oblique and lamelliform (*Silicula*). The beaks generally turn backward (*Yoldia*, *Leda*, *Nucula*), but in *Malletia*, *Tindaria*, and some other genera, they turn forward. On this account, when there is neither pallial sinus nor external ligament, it is often difficult, if not impossible, to tell which is the anterior end of the shell, without the soft parts. Hence many fossil and some recent species have possibly been reversed in the descriptions. Thus many of the palæozoic species referred to *Nucula* are described as having the beaks turned forward, the larger end of the shell being considered posterior; but in modern *Nuculæ*, the beaks turn backward, and the shorter end is posterior. Many of the deep sea species with small, thin shells show no distinct muscular nor pallial scars, which increases this difficulty. When a differentiated external ligament is present, we have assumed that it is posterior to the beaks (opisthodontic),

though a narrow extension usually runs under and forward of the beaks in a groove. When the shell of a dimyarian bivalve gapes posteriorly, the existence of a siphon may generally be assumed; for otherwise the internal soft parts would be exposed to enemies. The existence of a posterior rostrum or a protrusion of the posterior margin defined by an inferior emargination indicates the existence of a siphon, or at least an anal tube, but these organs may exist without such modifications of the shell. If these rules be applied to palæozoic forms we must conclude that the rostrate and subrostrate forms of *Palæoneilo*, etc., had some sort of a siphon, and therefore were not *Nuculidæ*, as now restricted.

Family NUCULIDÆ.

We have included *Nuculina* (D'Orb.) in the *Nuculidæ* with some doubt, because authors differ as to its structure. It is said that its ligament is wholly external; if so, it should, perhaps, form a distinct subfamily. Its anatomy is unknown. Fischer places it in the *Arcidæ*, near *Limopsis*, but it has no median ligamental area.

Subfamily GLOMINÆ, nov.

Ligament thick, elongated, attached for most of its length to the inner surface of the posterior hinge-plate and running forward in a narrow groove beneath the beaks, so that its anterior portion is external and the thickened posterior portion is partly internal. No pallial sinus. Animal not known.

This group includes, so far as known, only the genus *Glomus* Jeffreys, which has been referred by several writers to the *Arcidæ*, and by others to the *Ledidæ*, from both of which it differs widely. Its relations to the *Nuculidæ* are somewhat uncertain, owing to our ignorance of the soft parts. In the form and position of the ligament it differs entirely from all other genera of *Nuculidæ* and *Ledidæ*.

Glomus Jeffreys. Figures 1, 2.

Glomus Jeffreys, Annals, Mag. Nat. Hist., p. 433, 1876; Proc. Zool. Soc. London, p. 573, pl. xlv, figs. 5, 5a, 1879; Smith, Report Voy. Challenger, Zool., xiii, pp. 248-249, pl. xxi, figs. 1-3b, 1885.

Shell thin, smooth, sub-equilateral, rounded at both ends, with the beaks turned forward. No lunule nor escutcheon. Hinge with two series of obliquely transverse teeth; a small lateral tooth.

The following are described species:

G. nitens Jeff., *G. Jeffreysi* Smith, *G. simplex* Smith, *G. inæquilateralis* Smith, *G. Japonicus* Smith.

Family LEDIDÆ. Subfamily LEDINÆ.

Leda Schumacher, 1817. Figure 19. Type *L. rostrata* (Mont.).

This genus has been variously extended and restricted by authors, and several subgeneric and sectional groups have been proposed. In the more extended sense it is scarcely capable of a definition that will distinguish it from *Yoldia*, etc.

We propose, therefore, to restrict it to the typical species, such as *L. cuspidata* Gld., *caudata* Donovan (fig. 19), *pernula* (Müll.), *tenuisulcata* (Couth.) and many others, closely related. These have a long, tapered, bicarinate rostrum, and well-developed siphon tubes, partially united. The palpal tentacles are long, flat, tapered, and arise external to the bases of the outer palpi, which are broad, with slender, acute posterior tips.

Ledella, gen. nov. Figures 13, 18. Type *L. Messanensis* (Seg.).

Junonia Seguenza, *Nuculidi terziarie merid. d' Ital.*, R. Accad. Lincei, i, p. 1175, 1877 (not of Hübner).

This group includes a large number of small species, both living and fossil, in which the shell is rather short, usually ovate or swollen, with a small, acute, or subacute, unicarinate rostrum, situated medially or submedially, and defined below by an emargination or undulation in the postero-ventral margin. The postero-dorsal margin is usually convex. The escutcheon or ligamental area is distinctly defined by the carina, but is not sunken. The chondrophore is usually small but distinct. The siphon tubes are separate, at least in some species.

The following species appear to belong here:

L. seminula (Seg.), *L. Messanensis* (Seg.) (fig. 13), *L. Nicotrax* (Seg.), *L. peraffinis* (Seg.), *L. rectidorsata* (Seg.), *L. confusa* (Seg.), *L. solidula* Smith, *L. semen* Smith, *L. confinis* Smith, *L. inopinata* Smith, *L. prolata* Smith, *L. ultima* Smith, and *L. parva* V. & B.*

Portlandia Morch. Type *P. arctica* (Gray), 1819=*Leda Portlandica* (Hitch.).

We consider this a distinct genus, but would restrict it to the original type. In many respects this genus is intermediate between *Leda* and *Yoldia*. In its closed shell, definite rostrum,

* *Ledella parva*, sp. nov. Figure 18.

Shell minute, smooth, narrow ovate, inequilateral, obtusely rounded anteriorly, slightly rostrate posteriorly with a slight postero-ventral emargination; the short rostrum subtruncate at tip and defined by an inconspicuous ridge. Umbos somewhat swollen, beaks a little prominent and turned slightly backward. Hinge-plate strong with fifteen anterior and nine posterior teeth. Chondrophore rather small, triangular with a distinctly projecting inner margin. Length, 3^{mm}; height, 2^{mm}.

Station 2689, off Martha's Vineyard, in 525 fathoms, 1886.

etc., it agrees more nearly with the former, but in general outline, with the latter.

Yoldia Möller. Figures 12, 16. Type *Y. hyperborea* Torrell.

We propose to restrict this genus to the typical forms, such as *limatula* (Say) (fig. 12), *sapotilla* (Gld.) (fig. 16), *myalis* (Couth.) and many closely allied foreign species.

These have a nearly smooth, compressed, lanceolate, gaping shell, more or less prolonged and tapered posteriorly, with a poorly defined wide rostrum, generally without carinations. The external ligament is marginal, feebly developed, continuous under the beaks, and not much differentiated from the general epidermis. The chondrophore is large, concave, and projects within the margin. The pallial sinus is large and deep. The siphon-tubes and posterior pallial tentacle are long. The palpal tentacles are long and tapered; in life they may extend nearly to the end of the expanded siphon.

Orthoyoldia, gen. nov. Type *Orthoyoldia scapina* (Dall).

Shell oblong, gaping, blunt or rounded at both ends, without distinct rostrum; no carina. Pallial sinus large and broad. Teeth numerous in both series. *O. scapina* (Dall), from off Brazil, and *O. solenoides* (Dall), from the West Indies.

Megayoldia, gen. nov. Figure 17. Type *M. thraciæformis* (Storer).

Shell large, compressed, gaping, with a very short, blunt, indefinite, postero-dorsal rostrum. A low radial ridge, ends in a postero-ventral marginal lobe. A well defined but thin external marginal ligament extends both before and behind the beaks, anteriorly with a supramarginal furrow.

The chondrophore is remarkably large and strong, concave, striated within, and projects much within the margin of the hinge-plate. The pallial sinus is large and deep.

The postero-ventral margin of the mantle forms a pouch-like protrusion, corresponding to the radial ridge. The siphon tubes are long and united; the posterior pallial tentacle is long and slender. The palpi are very large. The palpal tentacles originate from the body wall at the base of the outer palpi; they are long and thick, with a large furrow on one side.

Yoldiella, gen. nov. Figures 3, 4, 11, 14. Type *Yoldiella lucida* (Loven).

This group includes a large number of small, mostly deep-sea species, with glossy, iridescent, ovate, and usually wedge-shaped shells, nearly always having a slight postero-ventral sinuosity,

which feebly defines an obscure, blunt, rostral region, without any definite carination. The shells do not gap, but close tightly, except that at the rostral angle of some species there may be a slight divergence. The internal cartilage, which is often relatively large, occupies a simple notch, which interrupts the hinge margin more or less completely and generally shows externally in a dorsal view; the notch usually terminates within on the inner or inferior surface of the hinge-plate and is often bounded within by a slight ridge. A weak external ligament is present on the postero-dorsal margin. A relatively small, pallial sinus has been observed in several of the species, but is usually indistinct. The siphon tubes, as observed in a few of the species, are slender and united for more than half their length.

The following are some of the species:

Y. lucida (Lovén), *Y. inflata* V. & B.,* *Y. Jeffreysi* (Hidalgo), *Y. lenticula* (Möller), *Y. frigida* (Torell), and *Y. Hoylei* (Smith).

Microyoldia, gen. nov. Figures 5, 6. Type *M. regularis* (V.).†

Shell small, tightly closed, veneriform, with the anterior end the shorter, with the beaks turned forward. A posterior marginal ligament in a distinct groove, continued under the beaks. Hinge-plate and teeth rather strong; anterior series of teeth the shorter, forming a marked angle with the posterior series. Internal cartilage supported by a relatively large and strong chondrophore, placed on the surface of the hinge-plate, distinctly behind the beaks and at the proximal end of the posterior series of teeth. Pallial line indistinct.

The curious little shell for which this genus is proposed is remarkable for its form and the internymphal position of the cartilage and chondrophore, as well as for its few short teeth. If we are correct in our conclusions as to the anterior and posterior ends, the beaks turn forward as in *Tindaria*.

Subfamily MALLETINÆ.

Malletia Desmoulins (restricted). Figure 9. Type *Malletia Chilensis* Desmoulins.

We propose to restrict this genus to those species having a nearly smooth, somewhat compressed, oblong or elliptical shell,

* *Yoldiella inflata*, sp. nov. Figures 3, 4, 11.

Shell small, smooth, shining, somewhat iridescent, swollen, rather short, subovate, inequilateral, broadly rounded anteriorly, broad and obtusely subtruncated posteriorly, with a slight angle at the upper extremity. Umbos well-rounded; beaks small, appressed to the margin. External ligament delicate. Hinge-plate moderately broad, with nine to eleven anterior and about ten posterior teeth, separated by the small cartilage pit. Epidermis pale olive-yellow or straw color.

Length of one of the largest specimens, 6^{mm}; height, 4.5^{mm}; thickness, about 3^{mm}.

Found at about twenty stations from south of Georges' Bank to Cape Hatteras, N. C., in 516 to 1608 fathoms, 1883-1886.

† Verrill, Trans. Conn. Acad., vi, p. 228, 1884.

blunt posteriorly, without any definite rostrum or carination. The carinated and rostrated species that have been placed in it will thus be referred to *Neilo* H. and A. Adams. The siphon tubes are long and united nearly to the tips.

The following are some of the known species:

M. Chilensis Desmoulins (Type), *M. obtusa* (Sars) Mörch, *M. pallida* Smith, *M. arrouana* Smith, *M. Dunkeri* Smith, and *M. Bellardii* Seguenza

The subgenus *Pseudomalletia*, proposed by Fischer for *M. obtusa*, was based on an erroneous description of the siphon tubes.

Neilo Adams. Type *N. Cumingii* Adams.

The type-species of this genus has an oblong shell, with a straight postero-dorsal margin and a well defined rostrum, bounded beneath by a pronounced furrow and a marginal indentation, while more ventrally the margin protrudes somewhat, the pouting of the margin corresponding with special lobes of the margin of the mantle. The type-species is concentrically grooved, but *N. goniura* Dall is smooth or nearly so.

Neilonella Dall. Figures 7, 8, 22. Type *N. corpulenta* Dall.

Saturnia Seguenza, Nuculidi terziarie merid. d'Ital., R. Accad. Lincei, i, p. 1178, 1877 (non Schrank, 1802).

Leda (section *Neilonella*) Dall, Bull. Mus. Comp. Zoöl., ix, p. 125, 1881; xii, p. 254, 1886 + *Saturnia*, op. cit., p. 253.

Shell ovate, with both ends obtuse; the posterior end somewhat longer than the anterior, without any distinct rostrum or carina. Exterior usually concentrically grooved. Ligamental area not defined. Beaks usually prominent and turned inward and slightly backward. External ligament well-developed; it extends under and before the beaks in a distinct groove, more prominent behind. Internal cartilage very minute or nearly abortive, occupying a slight notch in the medial dorsal margin, external to the series of teeth, which proximally become minute and are interrupted only by a small, thin edentulous space. Pallial sinus small. Siphon tubes short. Labial palpi large, broad, crescent-shape, with long tentacular appendages. Gills small, triquetral.

The following species appear to belong here:

N. corpulenta Dall (type), *N. quadrangularis* (Dall), *N. sericea* (Jeffreys), *N. pusio* (Phil.), and *N. subovata* V. and B.*

* *Neilonella subovata*, sp. nov. Figures 7, 8, 22.

Yoldia sericea Jeff. var. *striolata* Verrill, Trans. Conn. Acad., vi, p. 226, 1884.

Shell somewhat swollen, subovate, sculptured with regular concentric sulcations and ridges, usually faint or obsolete posteriorly, and with a number of faint radiating striae posteriorly. Beaks curved strongly inward and a little backward. Hinge margin rather strong, the series of teeth interrupted by a small edentulous space; eleven or twelve anterior and fifteen or sixteen posterior teeth. External ligament well-developed, dark brown, conspicuous behind the beaks, and extending a

Subfamily TINDARINÆ, nov.

Cucullellinæ (pars) Fischer, Man. Conch., p. 981. *Ctenodontidæ* Dall (pars), Trans. Wagner Free Inst., iii, p. 515, 1895.

In this group the shell is short-ovate or veneriform, with the posterior end the longer. The beaks turn forward. The internal cartilage is wanting. The external ligament is well-developed and prominent. The teeth are numerous, v-shaped, the two series are frequently continuous proximally. There is neither pallial sinus nor true siphons. The mantle is broadly open ventrally, but there is a separate anal or efferent orifice, surrounded by small sense papillæ. The palpi are large, with long slender appendages. Foot with a large, terminal, crenulated disk.

This group agrees with *Malletinæ* in having no internal cartilage, but there are, in the latter, well-developed siphons and a pallial sinus.

Numerous Palæozoic species referred to the genus *Palæoneilo* probably belong to or near this group. Some of the species* from the American Devonian rocks can hardly be distinguished from *Tindaria* by any important structural characters. It is probable that *Nuculites* and several related genera also belong to this division, for they have an external cartilage and no chondrophore. In these genera the plain transverse teeth are very numerous and more simple than in the modern genera, seldom showing any trace of the acute v-shaped form.

Mr. Dall has proposed the family *Ctenodontidæ* to include the extinct genera above named and others, but it is doubtful whether *Ctenodonta* itself belongs here. Zittell and others refer it to *Arcidæ*.

Tindaria Bellardi. Figures 10, 20, 21. Type *T. arata* Bellardi.

Several recent writers on these shells have regarded *Tindaria* as a subgenus of *Malletia*. In reality they form two widely diverse genera. In typical *Tindariæ* the shell is swollen, ovate, short, or subcordate, without any rostration, and with prominent umbos, with the beaks turned forward. In fact, the shells may be described as veneriform. The surface is usually concentrically grooved. The series of teeth are often continuous medially. There is no pallial sinus.

The following are some of the known species :

T. arata Bellardi, *T. solida* Seguenza, *T. cytherea* Dall = *T. veneriformis* Smith, *T. amabilis* Dall, *T. virens* Dall, *T. acinula*

little in front of them. Cartilage minute, marginal. Epidermis without much luster, either greenish yellow or light straw-color. Muscular impressions faint; sometimes a distinct angular pallial sinus is visible.

Length, 6.5mm; height, 4.6mm; thickness, about 3.5mm.

Found at many stations from off George's Banks to Cape Hatteras, in 125 to 1731 fathoms, 1883-1887.

* For examples see *P. constricta* Hall, *P. plana* Hall in *Palæontology of New York*, v, pt. I, pp. 333, 334, pl. xlviii, figs. 1-28, 1885.

Dall, *T. cuneata* Smith = *T. Smithii* Dall, and *T. callistiformis* V. and B.* All except the first two are from American waters.

Subgenus *Tindariopsis*, nov. Type *T. agathida* (Dall).†

This division is proposed for those species which have a short rostrum, defined by a radial ridge and a furrow. The type has a well-marked dorsal ligamental furrow and a small notch or "socket" under the beak for a specialized part of the ligament.

It is uncertain whether it has a siphon and pallial sinus. In case these are present, it should form a distinct genus and be referred to *Malletinæ*.

*Analytical table of recent subfamilies, genera, and subgenera of
Ledidæ and Nuculidæ here adopted.*

- A. Shell not gaping, short-ovate, subtrigonal, or rounded; posterior end without a rostrum; beaks usually curved backward; no siphon tubes nor pallial sinus.
 - Nuculidæ d'Orb.
- B. Shell more or less trigonal, usually oblique; posterior end usually shorter; beaks turned backward.....Nuculinæ.
- c. Teeth numerous, transverse, v-shaped, forming two convexly arched or angulated series; a distinct median chondrophore; no lateral teeth.....Nucula Lam.
- cc. Teeth few, not forming long series; a long lateral tooth in each valve; no median chondrophore.....Nuculina.
- BB. Shell rounded, nearly equilateral; beaks turned forward; teeth oblique, in two series; ligament in an elongated posterior internymphal groove.....Glominæ, nov.
- AA. Shell ovate, oblong or lanceolate; posterior end generally the longer and usually more or less rostrated; siphon tubes and pallial sinus generally present.....Ledidæ.
- C. Cartilage or resilium present, not closely united with the external ligament.....Ledinæ.
- a. Resilium supported by a definite concave chondrophore extending inward to or beyond the inner edge of the hinge-plate.
- b. Shell not gaping unless at the end of the rostrum.
- c. Shell distinctly rostrated and carinated posteriorly.

Leda Schum. (sens. ext.)

* *Tindaria callistiformis*, sp. nov. Figures 10, 20, 21.

Shell small, stout, thick, regularly ovate, sculptured with very regular fine concentric grooves. Umbos swollen, beaks prominent, curved strongly inward and somewhat forward. Hinge-plate with a continuous series of teeth, about eight before and twenty-three behind the beaks. Ligament groove rather deep, submarginal, both before and behind the beaks. Color pale yellowish brown, internally glossy, bluish white.

Length, 8mm; height, 6mm; thickness, about 4.5mm.

One living specimen, station 2566 off Chesapeake Bay, in 2620 fathoms, 1885.

† *Malletia* (*Tindaria*) *agathida* Dall, Proc. U. S. Nat. Mus., xii, p. 252, pl. xiii, fig. 10, 1889.

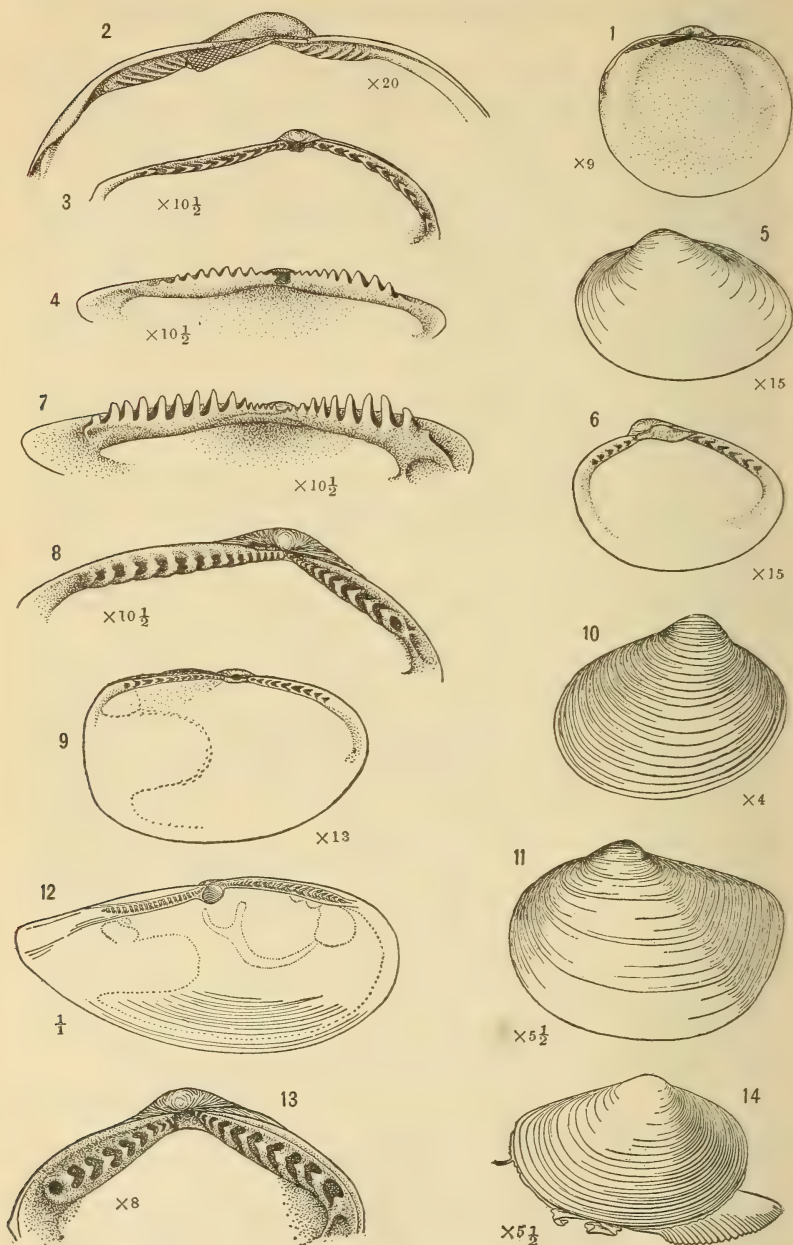


Fig. 1.—*Glomus nitens*, left valve. Fig. 2.—Hinge of same. Fig. 3.—*Yoldiella inflata* V. and B., hinge of left valve. Fig. 4.—Profile of same. Fig. 5.—*Microyoldia regularis* (V.) left valve. Fig. 6.—The same, right valve. Fig. 7.—*Neilonella subovata* V. and B., hinge of left valve, profile. Fig. 8.—The same, front view. Fig. 9.—*Malletia obtusa*, left valve. Fig. 10.—*Tindaria callistiformis* V. and B., right valve. Fig. 11.—*Yoldiella inflata* V. and B., left valve. Fig. 12.—*Yoldia limatula*, left valve. Fig. 13.—*Ledella messanensis* variety, left valve. Fig. 14.—*Yoldiella lucida*, from life, soft parts partly expanded. Figs. 12 and 14 are by J. H. Emerton; all others by A. H. Verrill.

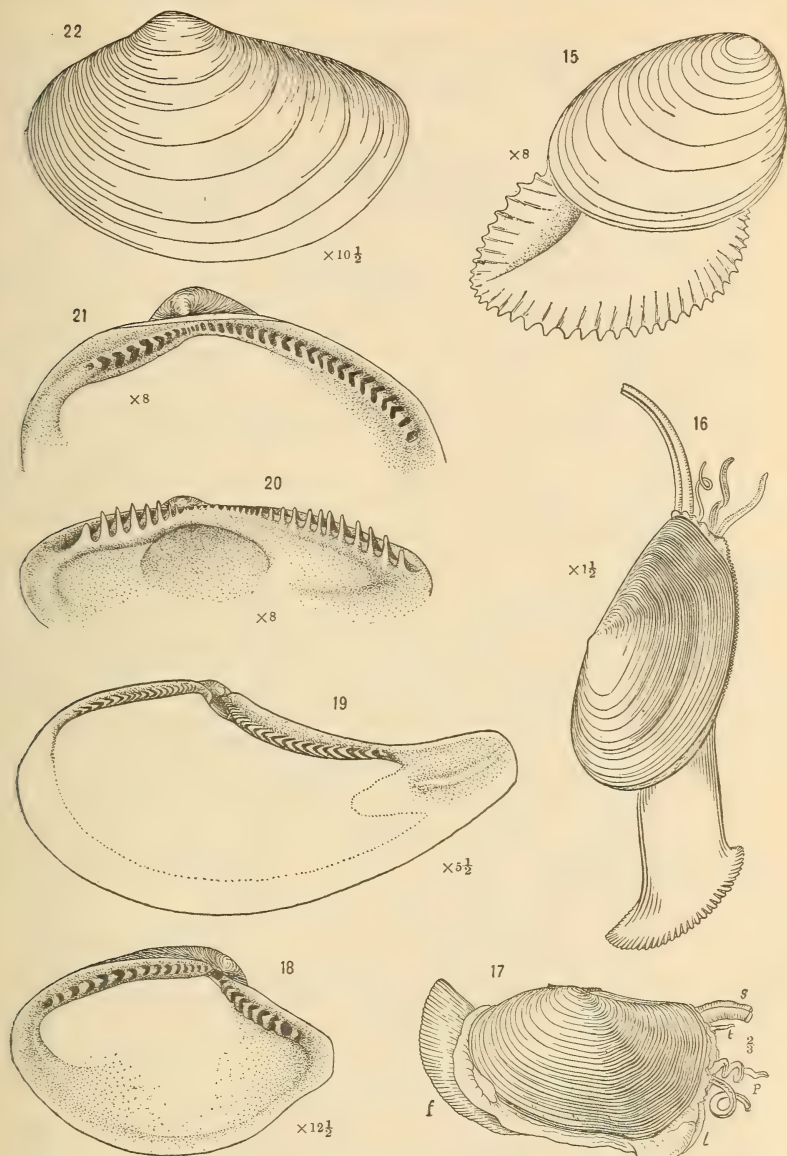


Fig. 15.—*Nucula proxima*, with expanded foot. Fig. 16.—*Yoldia sapotilla*, from life, with expanded soft parts. Fig. 17.—*Megayoldia thraciformis*, from life; *f*, foot; *l*, pallial pouch; *t*, pallial tentacle; *p*, palpal tentacles; *s*, siphon. Fig. 18.—*Ledella parva* V. and B., right valve. Fig. 19.—*Leda coudata*, right valve. Fig. 20.—*Tindaria callistiformis* V. and B., hinge of right valve, nearly in profile. Fig. 21.—The same, front view. Fig. 22.—*Neilonella subovata* V. and B., left valve. Figs. 15, 16, 17 are by J. H. Emerton; all others by A. H. Verrill.

- d.* Shell elongated and tapered posteriorly, rostrum long, bicarinate, blunt, ligamental area or escutcheon long and well-defined; pallial sinus and siphon tubes developed *Leda* (sens. rest.)
- dd.* Shell shorter, swollen, ovate or oblong, posteriorly not much elongated; rostrum short, usually acute, unicarinate.
- e.* Shell ovate, rostrum small acute; ligamentary area or escutcheon distinctly bordered by a carina.
- f.* Rostrum short, sub-acute, sub-median, defined below by a ventral-sinuosity or emargination.
Ledella, nov. = *Junonia Seguenza*.
- ff.* Rostrum short, dorsal, not defined below by a ventral sinuosity; postero-dorsal margin concave; escutcheon sunken *Jupiteria Bellardi*.
- ee.* Shell oblong, angular, subtruncate, rostrum short, angular, dorsal, defined below by a marginal sinuosity; escutcheon well defined *Portlandia Mörch*.
- cc.* Shell not rostrated, small, ovate or elliptical, rounded at both ends, anterior end the shorter, no carina, lunule, nor escutcheon; cartilage posterior, internymphal.
Microyoldia, nov.
- bb.* Shell oblong or lanceolate, compressed, nearly plain, more or less gaping at both ends; rostrum not well defined; pallial sinus large and broad; tubes long, united.
- g.* Teeth transverse, v-shaped, numerous, in two long series; chondrophore large, concave, projecting strongly inside the hinge-plate *Yoldia Möller* (sens. ext.)
- h.* Shell large, compressed, rounded anteriorly, broadest posteriorly with a postero-ventral protrusion and radial ridge; rostrum short, broad, poorly defined; external ligament well-developed, prominent both sides of the beaks, occupying a continuous furrow; no lunule nor escutcheon *Megayoldia*, nov.
- hh.* Shell lanceolate or long-ovate, posteriorly narrowed and somewhat elongated, more or less sinuous below; rostrum slightly defined, smooth or slightly carinate; external ligament feebly developed... *Yoldia* (sens. rest.)
- hhh.* Shell oblong, smooth, plain, blunt and rounded at both ends, without any distinct carina, sinuosity or rostrum.
Orthoyoldia, nov.
- hhhh.* Shell thin, compressed, narrow lanceolate or long elliptical, nearly equilateral, and gaping at both ends.
Adrana H. and A. Ad.
- gg.* Shell thin, oblong, inequilateral, blunt at both ends, not rostrated nor carinated; teeth few, lamellar, very oblique. Type *S. fragilis* Jeffreys... *Silicula* Jeffreys.
- aa.* Shell small, nearly plain, not much rostrated nor carinated; cartilage without a prominent chondrophore, situated in a notch in the hinge-margin, interrupting the series of teeth.

- l.* Teeth v-shaped, numerous in both series.
- m.* Shell oblong or subovate, blunt posteriorly, with a slightly sinuous margin, sometimes subrostrate, not carinate. Yoldiella, nov.
- mm.* Shell regularly ovate, rounded at both ends, not sinuous, nor carinate, (?) no pallial sinus Sarepta A. Ad.
- ll.* Shell short-ovate, not sinuous nor angulated; teeth few, oblique, not regularly v-shaped. Type *P. ovatus* Seguenza Phaseolus Seg.
- CC.* No true internal cartilage; ligament well-developed, often prominent behind the beaks. Beaks usually turned forward.
- D.* Siphon tubes and pallial sinus present; teeth mostly v-shaped, in two long series, often interrupted by a median edentulous space Malletinæ.
- o.* Siphon tubes long; pallial sinus large; shell elongated, gaping.
- p.* Shell oblong or elliptical, blunt posteriorly, not distinctly rostrate; series of teeth unequal; those in the anterior series fewer Malletia Desm.
- pp.* Shell long-ovate or oblong, broadly angulated and sinuous posteriorly; distinctly rostrate and carinate; two series of teeth nearly equal Neilo H. and A. Ad.
- oo.* Siphon and pallial sinus small, shell ovate, not gaping; a rudimentary marginal resilium. Neilonella Dall.
- DD.* Shell short-ovate or subcordate, closed at both ends; umbos prominent; ligament entirely external; series of teeth generally continuous Tindarinæ, nov.
- s.* Shell regularly ovate, grooved, without rostrum or carina; beaks turned forward; no pallial sinus. Tindaria Bellardi.
- ss.* Shell ovate, with a distinct posterior sinuosity and a short rostrum Tindariopsis, nov.

ART. VI.—*An Experiment with Gold*; by M. CAREY LEA.

SOMETIME since I had occasion to reduce a number of gold solutions and used for this purpose sodium hypophosphite. The solutions all acted in the usual way with one exception; in this the liquid turned deep emerald green. This condition lasted about ten minutes and then the metal was precipitated.

I have since determined the conditions under which this appearance takes place and its explanation.

A weighed quantity of pure gold was dissolved and the solution was evaporated to dryness twice. The chloride was then dissolved in water in the proportion of 1 gram of metallic gold to each 10^{cc} of solution. A 10 per cent solution of sodium hypophosphite was also made. These solutions mixed in various proportions produced the green solution; perhaps the most satisfactory result was obtained as follows:

Of the hypophosphite solution 15^{cc} are to be placed in a beaker and 1^{cc} of the gold solution is to be added and then one drop of sulphuric acid. As soon as the solution begins to darken a little, which will be in from two to four minutes, 30^{cc} of water are to be added without delay. The solution presently assumes a deep green color, remaining quite transparent. By slow degrees it becomes less clear. If filtered at the end of an hour the filtrate will either be yellow or green; if yellow it soon turns green, remaining for some time transparent; and this may be repeated several times.

One explanation presented itself—that there might be present in a state of fine division the olive green oxide of gold Au_2O_3 described by Prat.* But in the filtrations above referred to there is left on the filter an infinitesimal quantity of a blueish black substance which is not an oxide but metallic gold.

The green color of the liquid is, therefore, due to the presence of a small quantity of gold in its blue form in a state of very fine division, which together with the yellow of the undecomposed solution gives the effect of green.

If when the solution becomes slightly troubled, instead of filtering it is left to itself for a few minutes, the sides of the beaker will receive a deposit of gold, yellowish brown by reflected light but clear blue by transmitted.

* Roscoe & Schorlemmer, vol. ii, part 2, page 377.

ART. VII.—*Note on a new Meteorite from the Sacramento Mountains, Eddy Co., New Mexico;* by WARREN M. FOOTE. With Plates I and II.

ON nearing Fort Stanton, Arizona Territory, while on a westward journey in 1876, Mr. M. Bartlett of Florence, A. T., saw a meteor pass through the heavens in a southerly direction and fall, with a report like that of a cannon, on the east side of the Sacramento Mountains.

The above account was given by Mr. Bartlett to Mr. C. R. Biederman, and to the latter gentleman is due the credit of securing the specimen to science and furnishing the historical data here given.

Continued inquiry in the Pecos country was fruitless until by chance a small sample of native iron was presented to Mr. Biederman, for assay, and proving to be meteoric, led to the locating of the mass through the first finder, a shepherd, named Beckett.

The latter, in a sworn statement, says that he found it while herding in the lower foot-hills of the Sacramento Mountains, Eddy Co., N. M., about twenty-three miles southwest of a place called Badger. It rested on top of a limestone hill, where it had made a depression, and was partly buried. He could find no other pieces. Mr. Biederman, heading a search party, found the mass at the place indicated, and with much labor dragged it six miles over the desert to a wagon road. A long search was made by the party, but nothing else could be found. It is complete, save for about 500 grams of fragments, broken off by Beckett, and a piece of 1500 grams sawed off after it came into the possession of the firm of Dr. A. E. Foote. Its appearance indicates that no rupture occurred through an explosion during its flight nor by the force of the fall. The small fragments mentioned were employed in analysis and the making of a knife.

Description of the mass.—It is a typical example of the class of siderites, weighing complete about two hundred and thirty-seven kilograms, with general dimensions of about 80x60x20 centimeters. The exterior exhibits in a splendid manner the characteristic markings of meteoric iron. On the flat side, shown in Plate I, are two cup-shaped pits of 10 to 12 centimeters diameter which constitute a remarkable feature; the smaller depressions or "thumb-marks" of 3 to 4^{cm} diameter, which cover the remainder of the surface, are also reproduced in minute detail.

At the point where the fragments were removed the octahedral cleavage and lines of crystallization are noticeable to a

degree rarely seen in iron. It is, however, on the etched surface prepared through treating a polished slab with dilute nitric acid, in the usual manner, that the beauty of the crystal-line structure is best seen. In this respect it ranks among the finest of recorded irons, the Widmannstätten figures being exceptionally regular and distinct. The accompanying print (Plate II) was made directly from the etched surface. The broad bands of kamacite are symmetrical, the prominence of the interlacing of shining white threads of the niccoliferous iron being especially remarkable, and distinguishing it from the El Capitan meteoric iron, weighing about 28 kilos, and found* in 1893 about ninety miles north of the Sacramento range. In the latter iron the percentage of iron is less and nickel greater, phosphorous also being present. For a careful quantitative analysis the writer is indebted to Mr. J. Edward Whitfield (with Booth, Garrett & Blair, of Philadelphia), who obtained the following results :

| | |
|--------------|-----------------|
| Iron | 91.39 per cent. |
| Nickel | 7.86 “ |
| Cobalt | .52 “ |
| <hr/> | |
| 99.77 | |

The mass is perfectly preserved, there being no sign of disintegration or exudation of lawrencite. The sawing done shows it to be quite soft and generally homogeneous. The entire lack of surface alteration proves that it fell at a comparatively recent date, and leads to the conclusion that it is the meteor seen to fall by Mr. Bartlett, whose account led to the discovery.

Philadelphia, Dec. 15th, 1896.

* Prof. E. E. Howell, this Journal, vol. 1, p. 253.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Absorption Spectra of Iodine and Bromine solutions at Temperatures above the Critical Temperature of the Solvent.*—It is well known that the absorption spectrum of iodine in carbon disulphide consists of a narrow band in the red and a broad one in the violet, while that of iodine vapor consists of numerous fine lines. Wood has investigated the question whether a rise of temperature will convert the absorption spectrum into the line spectrum, by heating solutions of iodine in varying quantities of carbon disulphide in closed tubes to above 300° , the concentration of the iodine being varied until the line spectrum becomes visible. At this point the density of the carbon disulphide vapor and the concentration of the iodine were calculated and the results plotted. In the case of iodine the numbers obtained gave a curve consisting of two consecutive straight lines making an angle with one another, while the results of similar experiments with bromine gave a curve concave to the axis representing the concentration of the bromine. The ratio of the content of bromine to that of iodine at similar solvent density varied from 6.1 to 9.4 and increased with the concentration. The author points out the analogy between these results and those obtained by Hannay and Hogarth for solutions of solids at temperatures above the critical temperature of the solvent.—*Zeitschr. physikalische Chem.*, xix, 689-695, May, 1896. G. F. B.

2. *On Boiling Points in a Crookes Vacuum.*—KRAFFT and WEILANDT have studied the effect of very high exhaustions upon the boiling point of several organic substances. The pump used was that of v. Babo, a combination of the Bunsen water-pump with the mercury pump of Sprengel, working automatically and exhausting even a large vessel in a quarter to half an hour, so that a mercury manometer shows no difference of level on the two sides. To the distillation apparatus was attached a Hittorf tube, so that when the induction current was passed between its terminals the production upon the glass of the well known green fluorescence indicated approximately a vacuum of one millionth of an atmosphere. The substance was heated in a flask having a capacity of about 15° , which formed with the receiver a single piece. It was connected to the pump and the Hittorf tube by a ground joint, the thermometer passing through a rubber stopper in the neck of the flask. When in use, the receiver was covered with filter paper on which lumps of ice were placed. The substances experimented on, of course, were only those which at this temperature have no vapor-pressure; such as the higher paraffins, cetyl alcohol, chloride and iodide; the higher fatty acids and their amides; the higher acids of the oleic and oxalic series; alkylbenzenes of high molecular mass; mixed aliphatic-aromatic ketones of high molecular mass;

and sulphobenzide, dinaphthyl sulphides and sulphone. In all these cases it was found that a large lowering of the boiling point was brought about by the last small reduction of pressure; the difference in the boiling point at 15^{mm} pressure and in the Crookes vacuum varying from 70·5° in the case of cetyl alcohol, 78° in that of stearic acid and 98° in heptacosan $C_{27}H_{56}$, to 102° in the case of octadecylbenzene and 105° in that of pentadecylxylylketone.—*Ber. Berl. Chem. Ges.*, xxix, 1316, May, 1896. G. F. B.

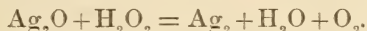
3. *On the Formation of Persulphuric Acid.*—The relation between the concentration of the sulphuric acid subjected to electrolysis and the amount of persulphuric acid formed, has been studied by ELBS and SCHÖNHERR. They determined the persulphuric acid by pouring 5 to 10^{cc} of the liquid into 200 to 300^{cc} of cold water, adding a known quantity of ammonium ferrous sulphate and then titrating back with potassium permanganate. They find that very little persulphuric acid is formed when the density of the sulphuric acid used is below 1·2; the maximum yield being obtained when this density is 1·35 to 1·5. Since the quantity of persulphuric acid produced is increased by an increase in the strength of the current, it must be formed by the union of the HSO_4 ions at the anode and is not due to oxidation: since in the latter case the amount formed would decrease rather than increase with the current strength. If the electrolyte be too concentrated, the yield is lessened, because (1) the concentrated acid is a bad conductor, (2) the molecules of $H_2S_2O_8$ when produced in a strong acid are not as free to move as in the more mobile dilute acid, and therefore, remaining longer at the anode, are to some extent decomposed, and (3) with concentrated acid, greater heat is developed and a greater number of molecules is thereby destroyed. Increase of temperature diminishes the amount of persulphuric acid formed, it being decomposed at 60° as rapidly as it is produced. If the acid be moderately dilute and the current strong, it is soon interrupted. On warming, however, the electrolysis begins anew, the interruption being caused by the formation of a non-conducting coating of $H_2S_2O_8$ at the anode. If the dilute acid have a density less than 1·3, no hydrogen peroxide, practically, is produced by the decomposition of the persulphuric acid. It increases, however, as the strength of the electrolyte increases. Persulphuric acid may be diluted with 50 times its volume of cold water without decomposition.

ELBS demonstrates the formation of persulphuric acid and of its potassium salt, by filling a wide test tube with the electrolyte, placing in it an anode consisting of a platinum wire enclosed in a glass tube for the greater part of its length, and a cathode made of a platinum ring. The bubbles of gas evolved are collected in a wider tube surrounding the anode and are thus prevented from reaching the cathode. The whole apparatus is placed in a beaker of cold water and a current is passed through it whose density is 100 amperes per square meter of anode surface. If the sulphuric acid have a specific gravity of 1·4, persulphuric acid can

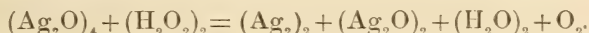
be detected at the anode in five minutes. Using a cold saturated solution of potassium sulphate in dilute sulphuric acid, a considerable amount of crystallized potassium persulphate may be obtained in 10 minutes. A longer time is required for the formation of the ammonium salt.—*Chem. Centr.* 1895, i, 591, ii, 476; *J. Chem. Soc.*, lxx, ii, 519, September, 1896.

G. F. B.

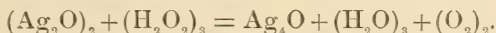
4. *On the Reaction of Silver oxide upon Hydrogen Peroxide.*—The equation expressing the decomposition of silver oxide by hydrogen peroxide was for a long time believed to be the following:



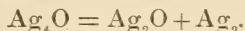
Berthelot, however, substituted for this the more complex equation:



RIEGLER has now studied this reaction more carefully and has come to the conclusion that neither of the above equations correctly represents the actual changes taking place. He therefore substitutes for them the following one:



Subsequently the silver oxide Ag_4O splits up into the oxide Ag_2O and free silver:



—*Chem. Centr.*, 1895, ii, 545; *J. Chem. Soc.*, lxx, ii, 471, August, 1896.

G. F. B.

5. *On Silver peroxyhydrate.*—The black deposit which is formed at the anode when a solution of silver nitrate is electrolyzed, and which was first observed by Ritter in 1814, has been investigated by SULC. The cathode was a platinum dish and the anode a strip of platinum foil cut in the form of a comb and rolled up. The solution contained 15 per cent of silver nitrate and a current of 0.06 ampere was employed, the density at the cathode being 0.0033 ampere per centimeter. After three or four hours, the solution, now contaminated with free nitric acid, was renewed. The crystalline deposit on the anode was removed by means of a glass rod and washed until free from silver. On analysis it gave numbers agreeing with the formula $\text{Ag}_7\text{NO}_{11}$. It was in the form of beautiful black octahedra having a metallic luster and a specific gravity of 5.65. In dry air it is fairly stable at the ordinary temperature, but when quickly heated to 155° it evolves oxygen and yields a voluminous dark brown powder. Water decomposes it only slightly, silver nitrate going into solution. When boiled with water for a day and a half, the silver is deposited in the form of a mirror. When boiled with alcohol, aldehyde is formed and a mirror deposited; this mirror being fine if a few drops of ammonia be added. Oxalic acid decomposes it completely with evolution of CO_2 ; and ammonia, with evolution of nitrogen. Since 1.40, the percentage of nitrogen, corresponds to a percentage of silver as AgNO_3 of 12.61, and since this

agrees with the analysis of the residue obtained on decomposing the substance with hot water, the author proposes the formula $(\text{Ag}_2\text{O})_3\text{O}_5\text{AgNO}_3$.—*Zeitschr. anorg. Chemie*, xii, 89–97, Feb., 1896.

MULDER and HERINGA have also examined this substance, preparing it by substantially the same process. The cathode was a liter reservoir of platinum and the anode was a platinum wire, a small glass vessel placed beneath serving to collect the black compound as it formed. In one series of experiments the solution was maintained neutral by means of silver carbonate, and in the other it was not neutralized. According to these authors, the substance obtained is liable to spontaneously decompose at the ordinary temperature, evolving oxygen. The analysis of the black compound obtained from concentrated solutions points to the composition $(\text{Ag}_2\text{O})_3\text{O}_5\text{AgNO}_3$; or perhaps $(\text{Ag}_3\text{O}_4)_2\text{AgNO}_3$ or $(\text{Ag}_2\text{O})_3\text{AgNO}_3$.—*Rev. Trav. Chim.*, xv, 1–51, 1896; *J. Chem. Soc.*, lxx, ii, 561, October, 1896.

G. F. B.

6. *On a new Hydrocarbon*, $\text{C}_{14}\text{H}_{12}$.—By dropping benzyl-ethyl ether into a flask provided with a return condenser and containing a mixture of phosphoric oxide and benzene, SCHICKLER has obtained a new hydrocarbon. At first the mixture is heated on the water-bath, but afterward, as the reaction becomes active, it is cooled. Ethylene is evolved and the liquid shows blue fluorescence. On distilling off the benzene and fractioning the residue, a clear, colorless aromatic liquid is obtained which can be crystallized by cooling, thus forming thick hard prisms, having the formula $\text{C}_{14}\text{H}_{12}$, and giving an odor like that of benzyl-ethyl ether. It fuses at 27° – 28° , boils at 253° – 254° , and is soluble in all the usual solvents, these solutions showing no fluorescence. It yields three nitro-compounds, two of which are crystalline and appear to be di-nitro derivatives fusing at 181° and 108° respectively, while the third melts at 75° and does not crystallize. It is dissolved and sulphonated by strong sulphuric acid.—*J. pr. Chem.*, II, liii, 369–374, May, 1896.

G. F. B.

7. *On Fractional Distillation of acids of the Acetic series*.—SOREL has applied to mixtures of the first four acids of the acetic series with water, the method of fractional distillation used by him with aqueous alcohol, the composition of the vapor at each instant being calculated from the curve representing the variations in the composition of the liquid in the retort. He finds that in dilute solutions the proportion of acid in the vapor is higher the greater the molecular mass of the acid. When the concentration increases the reverse is the case, the proportion being lower the greater the molecular mass. Hence mixtures of propionic or butyric acid and of water, of a certain composition distil unchanged as if they were definite hydrates. Moreover, butyric acid shows a peculiar phenomenon in that with any proportion of acid between 24 to 34 per cent, the composition of the distillate is independent of the composition of the liquid in the retort; its behavior being intermediate between that of miscible liquids and liquids which are partially or completely insoluble in one another.—*C. R.*, cxxii, 946–948, April, 1896.

G. F. B.

8. *Röntgen Rays*.—Mr. JOHN MACINTYRE in *Nature*, Nov. 18, 1896, gives an interesting account of his experiments with these rays. He obtained lantern slides of X-ray photographs by focusing the shadow on the fluoroscope screen on the ground-glass screen of an ordinary camera. In addition to the reduced picture of the shadow, he obtained also a picture of the brass mountings and lens of the camera. Hence a sufficient number of X-rays had passed through the screen to form a shadow picture of these objects. It appears that we are not utilizing all the X-rays that are ordinarily produced. The author therefore has advantageously employed a large and thick screen in which the crystals of the fluorescent substance are very much coarser than those ordinarily employed. He confirms the report of previous observers on the effect of the Röntgen rays in producing inflammation of the skin. The hand after being long exposed to their effect looks as if it had been sunburned; becomes red and swollen, and the severer effects remain for a fortnight. J. T.

9. *Rotation in Constant Electric Fields*.—In a very extended paper, QUINCKE gives the results of his observations on the movements of a large number of solid dielectrics immersed in fluid dielectrics, between the plates of a condenser. The constant electric field was obtained by the use of a Planté battery of twelve hundred cells. The author gives a minute description of the method of construction of this battery. He attributes the rotations of the solid dielectrics to the difference between the dielectric constant of the layers of air adhering to the rotating bodies and the dielectric constants of the bodies themselves.—*Ann. der Physik und Chemie*, No. 11, 1896, pp. 417-486. J. T.

10. *Interferential refractor for electrical waves*.—O. WIEDEBURG employs an apparatus for obtaining a difference of path which is analogous to that used by Jamin in his interferential refractor. Righi's apparatus for exciting and detecting short wave-lengths of electricity was employed. The author obtained for the index of paraffine, $n=1.418$; for that of glass, $n=2.63$.—*Ann. der Physik und Chemie*, No. 11, 1896, pp. 498-522. J. T.

11. *The Cadmium normal element*.—In a communication from the Physikalisches-Technische Reichsanstalt, W. JAEGER and R. WACHSMUTH give a careful determination of the temperature coefficient of the new Weston cell. They found that the change of electromotive force of the Weston cell, with a change of room temperature of 1°C ., was only $\frac{4}{1000}$ per cent, while with the Clark cell it is $\frac{1}{10}$ per cent. In reference to constancy and ease of reproduction it is not inferior to the Clark cell. Its electromotive force is 1.0184 volts. In the Clark element there is sometimes formed a layer of gas over the zinc amalgam, which raises the layer of zinc sulphate crystals, and therefore increases in a marked manner the resistance of the element. Together with this results a change of electromotive force. This defect does not enter in the use of the Weston cell, if the cadmium sulphate is removed by free acid.—*Ann. der Physik und Chemie*, pp. 575-591, No. 11, 1896. J. T.

II. GEOLOGY AND MINERALOGY.

1. *Geological Survey of Canada, Annual Report*. Vol. vii, for 1894. G. M. DAWSON, Director. Ottawa, 1896. — This volume includes eight special reports and accompanying maps (556, 557, 567, 571, 561, 562, 563); besides the Director's summary report of the operations of the survey for the year 1894, Dr. G. M. Dawson contributes a report on the area of the Kamloops map-sheet of British Columbia; R. G. McConnell one on an Exploration of the Finlay and Omenica rivers; D. B. Dowling on the country in the vicinity of Red Lake and part of Berens river, Keewatin; R. W. Ells on the southwest sheet of the "Eastern township of Quebec"; F. D. Adams on the Laurentian, north of the St. Lawrence; R. Chalmers, on the surface geology of parts of the Acadian provinces; G. C. Hoffmann on Chemistry and Mineralogy, and Messrs. Ingall and Brumell on the Mineral Statistics.

2. *Pleistocene glaciation in New Brunswick, Nova Scotia, and Prince Edward Island*.—Mr. ROBERT CHALMERS, in an interesting paper, published in the Annual Report of the Geology of Canada (vol. vii, 1894) on the surface geology of eastern New Brunswick, north-western Nova Scotia and a portion of Prince Edward Island, presents the following conclusions in regard to the glaciation of the region named:

Summarizing the principal facts relating to the Pleistocene glaciation of the region under review, it is found that at the period of the maximum extension of the ice there was a general radial movement from the main *névé*-ground of the north-east Appalachians, northward and eastward into the St. Lawrence Valley, eastward into the south-western embayment of the Gulf of St. Lawrence, south-eastward into the Bay of Fundy and Atlantic Ocean, and southward and south-westward in United States territory.

The St. Lawrence Valley, as far westward as the Thousand Islands, was probably an open channel in the latter part of the glacial period at least, into which ice flowed from the north and from the south.

Although the Appalachian glaciers here referred to were not of great superficial extent, the ice which occupied New England and south-eastern Quebec seems to have been the thickest and heaviest of the Pleistocene glaciers of eastern North America, developed in these latitudes; and the geographical and meteorological conditions favor the view that it was only surpassed in this respect by the great Cordilleran glacier of the west.

In eastern Canada, south of the estuary and Gulf of St. Lawrence, the land ice seems to have consisted of local glaciers, and the different parts which streamed outwards from the central *névé*-grounds have been differentiated and received separate names. That which occupied the Gaspé peninsula and the Notre Dame Range followed the drainage channels, generally speak-

ing, in its descent northward and southward. Along the lower St. Lawrence, the flow was apparently into the open waters of the estuary, while at Gaspé Basin it was eastward directly into the waters of the Gulf of St. Lawrence.

The western part of the Baie des Chaleurs Valley was occupied by a sheet to which the name of the Baie des Chaleurs glacier has been given. South of this and mantling the greater part of the Carboniferous area of New Brunswick and Prince Edward Island, the Northumberland glacier was developed. The great valley of the St. John River and the slopes on either side were occupied by a sheet of ice which has been designated the St. John Valley glacier. The east and south-east termini of these glaciers were attenuated and were not accompanied by moraines. During the epoch of maximum ice accumulation, the coast border was somewhat higher than at present. Subsidence and differential movements set in towards the closing stage of the glacial period, which, in the Carboniferous plain of central and eastern New Brunswick, are evidenced by a number of swerving courses of striae. These indicate that the watershed between the drainage basins of the St. John River and the rivers falling into Northumberland Strait did not partake of the downward movement of the coast border to such an extent as the latter. The striae, which show gradually swerving movements on the flat Carboniferous plain, may be taken as evidence that there was no withdrawal of the ice from the region during the whole glacial epoch. Towards the closing stage, the glaciers became smaller and more detached, and floating ice occupied the bays and straits. The markings left by the latter on rock surfaces show that the coastal parts of New Brunswick were then from 75 to 150 feet lower than at present. The country around the Baie des Chaleurs and that on the northern coast border of the Bay of Fundy, seem to have undergone greater differential changes of level than the central Carboniferous area of New Brunswick and Prince Edward Island, the latter area apparently occupying a more stable attitude in regard to crustal oscillations. The subsidence inaugurated then was that which continued into the Leda-clay period.

The peninsula of Nova Scotia was glaciated by land ice which gathered upon its surface, and probably by floating ice in the coast districts at a subsequent stage.

A local glacier seems to have accumulated around the head of Chignecto Bay and upon the isthmus of the same name, in the early stage of the Pleistocene, which has been called the Chignecto glacier. Floating ice has also glaciated the isthmus at a later date.

On the Magdalen Islands no evidences of Pleistocene ice-action, or of the occurrence of boulder-clay, were observed; on the contrary, the rock surfaces are everywhere masked with a covering of their own débris.

The cause or causes of the glacial period, or rather of the

existence of sheets of land ice in these latitudes in Pleistocene times, cannot be discussed here. But it may be remarked that the tendency to eliminate cosmic influences and attribute the refrigeration of the northern part of this continent to geographical or terrestrial causes, characteristic of later studies respecting glacial phenomena, does not seem, so far, to throw a great deal of light on the question, and may alter all be only a partial view. If the Glacial Period be wholly due to terrestrial causes, the fact that such causes must be largely of a local character appears to have been overlooked; for it is not probable that these causes would act synchronously in the whole arctic and north temperate zones as far south as the limits of the glaciated belt. That changes in the elevation of the land, changes in the distribution of land and water, changes in the atmospheric and oceanic currents, a greater or less amount of moisture and precipitation than what now obtains, etc., are, taken together, sufficient to bring about a glacial epoch, such as the phenomena indicate must have existed in Pleistocene times, may be seriously doubted. If it were attempted to show that such terrestrial conditions were sufficient to produce a glacial area locally, on one side or the other of the North American continent, for example, or on both sides of the North Atlantic, the hypothesis would seem to be adequate; but these causes, while competent to produce various local oscillations of climate and of glacial conditions, have probably been governed or modified by some general law. It is inferentially certain, therefore, that any hypothesis based on terrestrial conditions which may be propounded will have to include such general or cosmic influences as to affect simultaneously the whole circumpolar and north temperate regions of the earth during Pleistocene time, otherwise glacial conditions cannot have occurred synchronously in both hemispheres, or even on both continents.

3. *Notes sur la flore des couches permienes de Trienbach (Alsace)*; by R. ZEILLER. Bull. Soc. Géol. France, III, xxii, 1894, pp. 163-182, pl. viii, ix.—The material collected at Teufelsbrunnen, in the Forest of Honcourt, Alsace, from a thin series of shales, sandstones and conglomerates, comprising the "Trienbach beds" of Benecke and Van Werveke, has been found by M. Zeiller to include forty species of plants. This flora embraces ferns, *Sphenophylla*, *Calamariæ*, *Cordaitæ*, *Cycadææ*, *Coniferæ*, and fruits. While the greater number of the species are found in the upper part of the Carboniferous proper, nearly all are known to pass up into the Permian. On the other hand, several species have been found to be characteristic of the lower portion of the Permian; and the combined evidence leads Prof. Zeiller to correlate the Trienbach beds with those at Cusel, Stockheim, and Igornay, *i. e.*, the basal portion of the Permian.

From the paleontological standpoint this paper is of considerable systematic interest. Thus, from a study of abundant material, M. Zeiller is convinced that *Tæniopteris abnormis*, *T. fallax*, and *T. multinervis* are merely variations and phases, due

in part to circumstances of impression, of one species. We apprehend, however, that the last mentioned and later name, adopted by M. Zeiller on account of its priority in respect to correct diagnosis and illustration, will eventually yield to the one proposed by Gutbier, *Teniopteris abnormis*, though the latter was quite imperfectly described and figured.

Zamites Planchardi, found at Teufelsbrunnen, is compared with the five other species of *Zamites* distinguished by Renault in the Commeny basin, with the result that M. Zeiller is led to place all of them in the new genus *Plagiozamites*, which is characterized by its lanceolate, dentate leaves fixed by thickened, clasping or semi-clasping bases oblique to the plane of the rachis. Though unquestionably a Cycad, it has so much in common with *Noeggerathia* as to bring the author to regard the latter as belonging, not to the ferns, but to the *Cycadeæ*, the view entertained by Brongniart in 1849. In considering *Gomphostrobus bifidus*, a scale bifurcated at the top, to be a seminiferous scale of some conifer, Zeiller differs from Potonié, who regards it as a sporangiferous Psilotaceous leaf.

D. W.

4. *Artificial Production of the Mineral Northupite*.—An artificial chlorocarbonate of sodium and magnesium was described in 1893 by Winkler,* who observed it as an incrustation on the inside of iron cooling tubes used in working up saline solutions, rich in magnesium chloride, by the Solvay process. The same salt has recently† been prepared and described by DE SCHULTEN, who made it by adding to a solution of 20 grams anhydrous sodium carbonate and 150 grams sodium chloride in a round bottom flask, a solution of 15 grams of magnesium chloride. The flask was then heated on the water bath for seven to eight hours. The amorphous flocculent precipitate which the solution of magnesium chloride at first produced gradually contracted and transformed itself into brilliant crystals of the chlorocarbonate of sodium and magnesium. The salt has the same chemical composition as the mineral *northupite*, recently described in this Journal,‡ as will be seen from a comparison of the following analyses:

| | Salt (Winkler). | Salt (de Schulten). | Mineral (Pratt). | Theory for, MgCO_3 $\text{Na}_2\text{CO}_3\text{NaCl}$. |
|-----------------------|-----------------------------------|---------------------|------------------|--|
| Na_2O | 24.19 | 25.21 | 24.90 | 24.96 |
| MgO | 15.07 | 15.74 | 16.22 | 16.09 |
| CO_2 | 33.73 | 35.87 | 35.43 | 35.41 |
| NaCl | 22.59 | 23.64 | 23.45 | 23.54 |
| | 2.14 $(\text{NH}_4)_2\text{CO}_3$ | | | |
| | 1.92 CaCO_3 | | | |
| | .04 FeS | | | |

The physical properties of the salt are identical with those of the mineral.

De Schulten calls attention to the similarity of the salt and the

* Zs. für angewandte Chemie, p. 445, 1893.

† Bull. Soc. Franc. Min., vol. xix, Nos. 5-6, p. 164, 1896.

mineral northupite, of which Foote* had given a preliminary description and states that they are probably identical, which the subsequent quantitative analysis and the determination of the physical properties of the mineral† clearly show. J. H. P.

5. *The genesis of the Talc deposits of St. Lawrence Co., N. Y.*—A paper by C. H. SMYTH, JR., in vol. xvii of the *School of Mines Quarterly*, gives the results of the author's minute study of the talc deposits of St. Lawrence Co., in northern New York. He concludes that the talc is doubtless pseudomorphous, and that the original minerals were tremolite and enstatite, to which it owes its common fibrous character. He recognizes three distinct stages in the origin of the deposits: first, the formation of an impure siliceous and magnesian limestone; second, the conversion of this into enstatite and tremolite schist by metamorphosis; third, the change of this schist into talc by the action of water charged with carbon dioxide.

6. *A Handbook of Rocks for use without the Microscope*; by JAS. F. KEMP. 8°, 176 pp. (Pub. by author, 1896.)—This little handbook will undoubtedly be found of great service to field geologists, engineers, chemists, and in short all those who desire more definite and special knowledge about rocks than is found in geological text-books, and yet who do not desire to approach the subject from the difficult side of microscopical petrography. One of the chief merits of the work is that it does not attempt to tell too much by exchanging clearness for brevity. It is evident that only the broadest distinctions and simplest of classifications can be made without the use of the microscope, and that complicated methods for determining all rocks by megascopic properties must necessarily be unsatisfactory. Wisely recognizing this, the author has confined himself to telling such things about rocks as it is possible to learn without the microscope. The tables of analyses and discussions of the chemical composition are an excellent feature. The value is also greatly enhanced by a very full glossary in the end. L. V. P.

III. BOTANY AND ZOOLOGY.

1. *An Illustrated Flora of the Northern United States, Canada, and the British Possessions from Newfoundland to the Parallel of the Southern Boundary of Virginia, and from the Atlantic Ocean westward to the 102d meridian*; by NATHANIEL LORD BRITTON, Ph.D., and Hon. ADDISON BROWN. In three volumes. Vol. 1, Ophloglossaceæ to Alzooaceæ. New York, 1896 (Charles Scribner's Sons).—Believing sincerely that whatever stimulates the study of Natural History is a substantial gain, we welcome this treatise. Its typography and profuseness of illustration cannot fail to attract many readers who will use it as an agreeable introduction to the pursuit of botany. To the system of nomenclature which has been adopted, we cannot, at this stage of what promises

* This Journal, vol. 1, p. 480, Dec. 1895, and vol. ii, p. 124, Aug. 1896.

to be a long discussion, give approval; in fact we do not quite understand the relation which this work sustains to the association check-list recently promulgated, nor do we favor the liberty which has been taken with many species. Critical comments relative to disputed cases can, however, be better left until the completion of the work. As the treatise appears to be in a state of promising forwardness, we may not have long to wait for the remaining volumes. We congratulate the authors on their success in conducting this work. Whatever divergence of views there may be in regard to certain descriptions, names, ranges and figures, there can be but one opinion as to the remarkable energy with which this undertaking has been carried on. The authors have made what must, in all fairness, be regarded as a very important and, we hope, useful contribution to our knowledge of American plants. The price at which this work is sold is extremely low, and should ensure its finding a place on the working table of amateurs and professional botanists throughout its range.

G. L. G.

2. *Notes on the Flora of Newfoundland*; by B. L. ROBINSON and H. VON SCHRENK.—As a matter of record we call attention to this interesting paper in the January and April numbers of the Canadian Record of Science. The authors visited the island in 1894, and made such collections as were possible in the last days of July and nearly the whole of August. They added more than a hundred species which had not hitherto been recorded as found in the island.

G. L. G.

3. *The Survival of the Unlike. A collection of Evolution Essays suggested by the study of Domestic Plants*; by L. H. BAILEY. New York, 1896 (The Macmillan Co.).—This interesting volume takes its name from the first essay in its pages. The author holds that the unlikenesses in plants are (1) the expressions of the ever-changing environmental conditions in which plants grow, and of the incidental stimuli to which they are exposed; (2) the result of the force of mere growth; (3) the outcome of sexual mixing. They survive *because* they are unlike, and thereby enter into fields of least competition. Leaving out the second of these categories, the position is a strong one, and it is well maintained. Professor Bailey believes, and we cannot believe otherwise in view of horticultural experience, that plants can be profoundly modified by different external conditions, and that these modifications tend to persist. We are greatly indebted to the author for the untiring assiduity with which he has pursued the task of accumulating evidence and for the skill with which he marshals his proofs.

G. L. G.

4. *Sphagna Boreali-Americana Exsiccata*; curaverunt D. C. EATON et E. FAXON, New Haven, 1896.—In June, 1893, Prof. Eaton and Mr. Faxon issued a prospectus of an intended distribution of sets of North American *Sphagna*, but the death of Prof. Eaton in June, 1895, made it necessary for his son, Mr. G. F. Eaton, to complete the arrangement of the sets prepared by

Mr. Faxon and his father. Sixty sets, each containing 172 numbers, representing 39 species and their varieties and forms, have been prepared and form a collection indispensable to all students of Sphagna. Specimens of all the species and varieties were sent by Prof. Eaton to the well-known sphagnologist, Dr. C. Warnstorf, whose suggestions as to nomenclature have been closely followed. The specimens are remarkably fine and offer a richness of material for the study of North American forms of the genus unequalled by any previous collection. The eastern portions of the United States are very fully represented by specimens collected mainly by Mr. Faxon and Prof. Eaton. The forms from the South and West, though not so fully, are well represented by the contributions of a number of well-known collectors. The distribution of the sets is in charge of Mr. G. F. Eaton, whose address is 70 Sachem street, New Haven, to whom those desiring sets should apply for information.

W. G. F.

5. *Analecta Algologica, Continuatio III.* By Prof. J. G. AGARDH. Lund., 1896, pp. 140, pl. I. 4°.—This valuable contribution forms apparently the final portion of the series of *Analecta*, since it includes an index to the whole work. The present portion covers a large field and the author gives a revision of *Punctaria* and its allies, including the new genera *Homœostroma* and *Nematophlœa*; a revision of *Phyllitis* with the new genus *Endarachne* represented by *E. Binghamiæ* from California; notes on Australian *Eckloniæ* and revisions of the genera *Cystoseira* and *Cystophora* and the Japanese *Largassa*; and remarks on various *Florideæ*, including a revision of *Chylocladia* and *Liagora*. Among North American forms are several new species of *Liagora*, and the new genus *Hooperia*, founded on *Chylocladia Baileyana*, Harv.

W. G. F.

6. *Phycotheca Boreali-Americana*; by F. S. COLLINS, ISAAC HOLDEN and W. A. LETCHELL.—The fifth fascicle of this series has recently been issued, and like its predecessor includes a large number of interesting Nostochineæ, 18 in all, together with Ehlorosporeæ and Florideæ. We may mention *Anabaena catenula*, var. *Americana*, *A. Barnetiana*, recently described in *Erythea* by Mr. Collins, *Enteromorpha cruciata* Collins, *Codium mucronatum* var. *Californicum*, and *Ceramium codicola*.

W. G. F.

7. *Ueber das Verhalten der Kerne bei den Fruchtentwicklung einiger Ascomyceten*; by R. A. HARPER.—The present paper from Pringsheim's Jahrbuecher is a continuation of one already noticed in the April number of this Journal. In that paper he gave an account of his study of the development of the perithecia of *Sphaerotheca*, in which only a single ascus is formed. Here he extends his observations to perithecia with several asci as illustrated by *Erysiphe communio*. In this case, the fertilized egg-nucleus divides into two and then into four and the oogonium increases in length with the formation of cross-septa until it forms a curved tube with a row of from five to eight nuclei. The septa then form simul-

taneously so that the cell next to the terminal one contains two or even more nuclei. From this cell arise the hypha which are to bear the asci, although the tangle formed by the ascogenaus hyphæ is so great that it cannot be asserted with certainty that some of the hyphæ arise from the adjoining cells of the tube. The cells which ultimately form the asci can always be recognized by their large size and by having two nuclei. An account is given of the development of the perithecial wall and the conidial spores in *Erysiphe*. A less minute account is given of the development of the fruit in *Ascobolus*, in which the interesting point is brought out that the septa in the Ascogonium are perforated in the center. The paper closes with some very suggestive general remarks on the relation of the fertilization in Ascomycetes to that in Florideæ. The union of nuclei in asci and basidia, which has been considered a sexual act by a number of recent writers, is not so interpreted by Dr. Harper. In the *Erysipheæ*, at least, the real sexual process is found in the union of the nuclei of the antheridium and the oozonium.

W. G. F.

8. *A gigantic Cephalopod on the Florida coast.*—MR. R. P. WHITFIELD has forwarded to the writer the following letter from Dr. Webb to Mr. J. A. Allen, dated St. Augustine, Fla., Dec. 8th, 1896:

"You may be interested to know of the body of an immense Octopus thrown ashore some miles south of this city. Nothing but the stump of the tentacles remain, as it had evidently been dead for some time before being washed ashore. As it is, however, the body measures 18 feet in length by 10 feet in breadth. Its immense size and condition will prevent all attempts at preservation. I thought its size might interest you, as I do not know of the record of one so large."

The proportions given above indicate that this may have been a squid-like form and not an *Octopus*. The "breadth" is evidently that of the softened and collapsed body, and would represent an actual maximum diameter in life of at least 7 feet, and a probable weight of 4 to 5 tons for the body and head. These dimensions are decidedly larger than those of any of the well-authenticated Newfoundland specimens. It is perhaps a species of *Architeuthis*. Professor Steenstrup recorded many years ago a species of this genus (*A. dux*),* taken in 1855 in the West Indian seas, but his example was much smaller than the one here recorded.

A. E. VERRILL.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *A History of Elementary Mathematics, with hints on methods of teaching*; by FLORIAN CAJORI, Ph.D., Professor of Physics in Colorado College. pp. 304. New York, 1896 (The Macmillan Company).—A book which presents the most important part of the history of mathematics in a form attractive

* See Trans. Connecticut Acad., vol. v. Also Report U. S. Fish Commis. for 1879, p. 51, pl. 12, fig. 4.

to laymen is worthy of a hearty welcome. Many excellent histories are to be found on the shelves of our libraries, but few, if any, are sufficiently elementary and untechnical to tempt any but the trained mathematician.

As far as Arithmetic, Algebra, Geometry and Trigonometry are concerned, few will have occasion to go beyond this book, and those few will find all necessary directions in its copious footnotes and references.

One main purpose of the author, as avowed in the preface, is to offer suggestions for the guidance of teachers based on the sound principle that "the education of the child must conform both in mode and arrangement with the education of mankind, as considered historically;" but the chief benefit to be derived from it by any reader, whether he be a teacher or not, consists in the stimulating and liberalizing effect of such a general view of the development of the human intellect in a direction where that development has been so free and characteristic. Any student with the training of the average freshman can read the book with profit, and many a student who has traveled from the multiplication table to spherical triangles as through a dry and thirsty land, would by such reading be brought to see a new meaning in the region through which he has come and even to find it full of dignity and beauty as the scene of the labor and achievement of so many centuries.

W. B.

2. *An Eclipse Party in Africa: Chasing Summer Across the Equator in the U. S. S. Pensacola*; by EBEN J. LOOMIS, Senior Assistant U. S. Nautical Almanac Office. 218 pp. Boston, 1896 (Robert Brothers).—The Scientific results of the American Solar Eclipse Expedition to Africa in the latter part of the year 1889 have already been presented in a number of scientific journals. It has remained for Mr. Loomis to give a popular account of the experiences of the party. This he does in a most attractive way in the present volume. The reader starts off with the U. S. S. *Pensacola* from Brooklyn, on the 16th of October, and has a delightful journey to the Azores, the Cape Verde Islands, and along the west coast of Africa to St. Paul de Loanda and Cape Ledo, where the party disembarked and the astronomical instruments were set up for use. An interesting account follows of the course of the eclipse, unfortunately not observed under the best conditions for scientific results; when the work there was through, the journey was continued to Cape Town and then back by St. Helena, the Ascension Islands and the Barbadoes to the starting point, which was reached May 23, 1890. A side trip to the Kimberley diamond mines afforded the writer a chance to give an account of the many things of interest which he saw and learned there. Indeed, the volume is throughout both entertaining and instructive, and its interest is much increased by the large number of excellent half-tone plates, chiefly from photographs taken by members of the expedition.

3. *Elementary Meteorology for High Schools and Colleges*; by FRANK WALDO, Ph.D. 373 pp. 12mo. New York, 1896.

(American Book Company).—This new elementary text-book, in a department in which the teacher has thus far had but little choice open to him, can be heartily commended. The author's practical experience in connection with the Weather Bureau has aided him in presenting the fundamental facts and principles of the science clearly and systematically and with all needed illustration. The treatment is brief, as must necessarily be the case in a book so limited in size, but this does not seem to have impaired the accuracy of the statements. Detailed descriptions of instruments have been wisely omitted. The figures are numerous and good.

4. *The Meteor of December 4th.*—A meteor, of unusual size and brilliancy, was observed from numerous points in southern New England and New York on the afternoon of December 4th, shortly after half past four o'clock. An observer in Brooklyn (Mr. Gustav Müller) gives the time of its appearance as 4^h 41.1^m, the direction E.N.E., and the course nearly vertical downward with a slight curvature to the north from an altitude of 50° to 20° when it disappeared, apparently obscured by clouds. He estimated the duration as from 2 to 3 seconds; the form was that of an elongated ovoid; a bluish or greenish tinge of color in the blazing mass was noted. From New Haven, Conn., the meteor appeared at sensibly the same hour in a direction about E.S.E.; the same brilliant color was noted, but the sky was partially obscured by clouds. The observations recorded suggest that the mass may have fallen in the eastern part of Long Island Sound.

OBITUARY.

BENJAMIN APTHORP GOULD. In the death of Dr. Gould, which occurred at his home in Cambridge, Mass., on the evening of November 6, 1896, science has suffered a heavy loss. Though for the past two years his health had been seriously impaired from the effects of an accident, he was still able to accomplish an amount of work which might have satisfied many younger men; and he enjoyed the capacity to work up to the day of his death.

Benjamin Apthorp Gould was born in Boston, September 7, 1824. Descended from a line of educated men, he was carefully trained in the classics and the humanities. During his whole life he continued to cultivate his mind with the wit and philosophy of all ages, wherein he seemed to find his keenest enjoyment. Joined to these attainments was that of an accomplished linguist; thus he was not only a man of ripe and accurate scholarship, but he was a cosmopolitan as well.

Soon after his graduation from Harvard College in 1844, he spent about three years in Europe, visiting in turn the most important astronomical observatories, in order to obtain instruction in astronomy from the acknowledged masters of that science. Thus he acquired not only a high degree of professional training, but he was also enabled to transplant to this country the inherited traditions of astronomical science, which are so valuable in obtaining a proper perspective over the history of astronomy and as an aid to the guidance of its future.

While Dr. Gould was a citizen of the world, and corresponded with his intimate friends in at least four different languages, he was most intensely devoted to the promotion of science in his native land. As one means to this end he established the *Astronomical Journal* in 1848. He sustained its publication to a large extent from his own private means, and he lavished upon it earnest solicitude and unremitting care to make of it a worthy representative of American science as well as a record of valuable scientific investigations. Though Dr. Gould was obliged to suspend the publication of the *Astronomical Journal* from 1861 to 1886, this periodical had entered upon its seventeenth volume at the time of his death, established more firmly than ever as the organ of American astronomy.

There is not space here to mention all the important scientific works and occupations of Dr. Gould, even in outline. The most notable may receive passing notice. From 1852 to 1867 he was in charge of telegraphic longitude determinations for the U. S. Coast Survey. He developed the methods employed, and determined the first transatlantic longitude by telegraph. During the Civil war, while in the service of the Sanitary Commission, he pursued extensive investigations in Anthropometry, the results of which he published. Also, during the period 1848 to 1870, he effected the reduction of various extended series of astronomical observations,—notably the meridian observations made by D'Agelet in Paris near the close of the last century.

His great and distinctive work, however, is comprised in the survey of the southern sky which occupied him during the period from 1870 to 1885. During this time he secured the founding and directed the labors of a National Observatory at Cordoba in the Argentine Republic. Here, with immense industry, and with a perseverance which remained undaunted in the face of great obstacles and personal afflictions, he completed a critical and exhaustive uranometry of the southern sky, and he supplemented the zone-observations of Bessel and Argelander by his own observations of 73,160 stars south of -23° of declination, much surpassing these predecessors in the precision of measurement attained. Besides these labors, his catalogue of 32,448 of the brighter stars in the Southern hemisphere contains the results of more than 150,000 meridian observations of precision,—a work which has not been equalled in extent, nor surpassed in value, by any other similar work in astronomy.

Dr. Gould, in coöperation with Mr. Rutherford, was a pioneer in developing the application of photography to astronomy of precision. He made extensive use of celestial photography during his stay in South America. The elaboration of this material in an extensive memoir, which he left substantially complete, was the last great undertaking of his life.

He was one of the founders of the National Academy of Sciences. He was elected an honorary member of the principal Academies of Science in Europe; he became a knight of the order *pour le mérite* of the German Empire; and he received other honors and medals too numerous to admit of mention here.

CATALOGUE
OF THE
COLLECTION OF METEORITES
IN THE
PEABODY MUSEUM OF YALE UNIVERSITY.

METEORIC STONES.

| | Date of Fall. | Locality and Catalogue Number. | Weight in grams. | |
|----|----------------|---|------------------|--------|
| | | | Largest mass. | Total. |
| 1 | 1492, Nov. 16 | Ensisheim, Elsass, Germany (1). | 13 | 18 |
| 2 | 1768, Nov. 20 | Mauerkirchen, Upper Austria (76). | 12 | 12 |
| 3 | 1790, July 24 | Barbotan, Landes, France (55). | 15 | 15 |
| 4 | 1794, June 16 | Siena, Tuscany, Italy (77). | 6 | 7 |
| 5 | 1798, Dec. 19 | Benares (Krakhut), Bengal, India (2). | 1 | 1 |
| 6 | 1803, April 26 | L'Aigle, Orne, France (3). | 902 | 902 |
| 7 | 1807, Dec. 14 | Weston, Connecticut (4). | 14,625 | 14,880 |
| 8 | 1808, April 19 | Parma (Borgo San Donino), Italy (5). | 10 | 10 |
| 9 | 1808, May 22 | Stannern, Iglau, Moravia (6). | 76 | 107 |
| 10 | 1810, Nov. 23 | Charsonville, Loiret, France (7). | 9 | 9 |
| 11 | 1811, July 8 | Berlanguillas, Burgos, Spain (8). | 14 | 14 |
| 12 | 1812, April 15 | Erxleben, Magdeburg, Prussia (48). | 13 | 13 |
| 13 | 1812, Aug. 5 | Chantonay, Vendée, France (9). | 39 | 42 |
| 14 | 1814, Feb. 14 | Bakhmut (Alexejewka), Russia (10). | 2 | 2 |
| 15 | 1814, Sept. 5 | Agen, Lot-et-Garonne, France (61). | 7 | 7 |
| 16 | 1815, Feb. 18 | Durala, Punjaub, India (11). | 3 | 3 |
| 17 | 1818, Aug. 10 | Slobodka, Smolensk, Russia (12). | 2 | 2 |
| 18 | 1819, June 13 | Jonzac, Charente Inférieure, France (13). | 2 | 2 |
| 19 | 1822, Nov. 30 | Futtehpur, N. W. Provinces, India (14). | 36 | 36 |
| 20 | 1822-23 | Umballa, Punjaub, India (15). | 1 | 1 |
| 21 | 1823, Aug. 7 | Nobleboro, Lincoln Co., Maine (78). | 7 | 7 |
| 22 | 1825, Feb. 10 | Nanjemoy, Charles Co., Maryland (16). | 897 | 897 |
| 23 | 1825, Sept. 15 | Honolulu, Hawaii, Sandwich Islands (17). | 577 | 577 |
| 24 | 1827, May 9 | Drake Creek (Nashville), Tennessee (18). | 425 | 425 |
| 25 | 1828, June 4 | Richmond, Virginia (19). | 311 | 311 |
| 26 | 1829, May 8 | Forsyth, Monroe Co., Georgia (20). | 132 | 132 |
| 27 | 1831, May 13 | Vouillé, near Poitiers, France (21). | 5 | 5 |
| 28 | 1838, Aug. 18 | Akburpur, Saharanpur, India (22). | 1 | 1 |
| 29 | 1838, June 6 | Chandakapur, Berar, India (23). | 41 | 41 |
| 30 | 1838, Oct. 13 | Cold-Bokkeveldt, Cape of Good Hope (24). | 96 | 110 |
| 31 | 1839, Feb. 13 | Little Piney, Pulaski Co., Missouri (25). | 24 | 24 |
| 32 | 1841, June 12 | Chateau Renard, Loiret, France (26). | 91 | 91 |
| 33 | 1842, April 26 | Milena (Miljana) Warasdin, Croatia (63). | 7 | 7 |
| 34 | 1843, Mar. 25 | Bishopville, Sumter Co., So. Carolina (28). | 211 | 211 |
| 35 | 1843, June 2 | Utrecht, (Blaauw-Kapel), Holland (27). | 4 | 4 |
| 36 | 1845, Jan. 25 | Le Pressoir, Indre-et-Loire, France (80). | 4 | 4 |
| 37 | 1846, May 8 | Monte Milone, Macerata, Italy (29). | 3 | 3 |
| 38 | 1846, Aug. 14 | Cape Girardeau, Missouri (67). | 1,495 | 1,637 |
| 39 | 1847, Feb. 25 | Linn Co. (Hartford), Iowa (30). | 666 | 1,062 |
| 40 | 1848, May 20 | Castine, Hancock Co., Maine (79). | 16 | 16 |
| 41 | 1849, Oct. 31 | Cabarras Co. (Monroe), North Carolina (31). | 231 | 231 |
| 42 | 1850, June 13 | Kesen, Iwate, Japan (81). | 424 | 424 |
| 43 | 1850, Nov. 30 | Shalka, Bancoora, Bengal, India (32). | 1 | 1 |
| 44 | 1851, April 17 | Gütersloh, near Minden, Westphalia (33). | 4 | 4 |
| 45 | 1852, Jan. 23 | Nellore, (Yatoor), Madras, India (34). | 27 | 47 |
| 46 | 1852 Sept. 4 | Mezô-Madaras (Fekete), Transylvania (35). | 20 | 20 |
| 47 | 1852, Dec. 2 | Bustee, near Goruckpur, India (82). | 12 | 12 |

METEORIC STONES—*Continued.*

| | Date of Fall. | Locality and Catalogue Number. | Weight in grams. | |
|----|----------------|---|------------------|-----------|
| | | | Largest mass. | Total. |
| 48 | 1853, Mar. 6 | Segowlee, Bengal, India (36). | 46 | 46 |
| 49 | 1855, May 11 | Oesel Island, Livonia, Russia (37). | 6 | 6 |
| 50 | 1855, Aug. 5 | Petersburg, Lincoln Co., Tennessee (49). | 15 | 15 |
| 51 | 1856, Nov. 12 | Trenzano, Brescia, Italy (83). | 43 | 43 |
| 52 | 1857, Feb. 28 | Parnallee, Madras, India (38). | 944 | 1,956 |
| 53 | 1857, April 18 | Kaba, Debreczin, Hungary (84). | 0.5 | 0.5 |
| 54 | 1858, Dec. 9 | Aussor (Montrejeau), Hte. Garonne, France (59) | 18 | 18 |
| 55 | 1859, Mar. 28 | Harrison County, Indiana (39). | 17 | 17 |
| 56 | 1859, July 4 | { Miney, Taney Co., Missouri (99). Newton Co., Arkansas (52). | 67 7 | 67 7 |
| 57 | 1860, May 1 | New Concord, Guernsey Co., Ohio (40). | 6,718 | 6,718 |
| 58 | 1860, July 14 | Dhurmsala, Punjab, India (68). | 38 | 38 |
| 59 | 1861, May 12 | Butsura (Qutahar Bazaar), Bengal, India (41). | 92 | 92 |
| 60 | 1863, June 2 | Buschhof, Kurland, Russia (42). | 22 | 22 |
| 61 | 1863, Aug. 8 | Pillistfer, Livonia, Russia (43). | 11 | 11 |
| 62 | 1863, Dec. 7 | Tourinnes-la-Grosse, Tirlemont, Belgium (64). | 4 | 4 |
| 63 | 1863-64 | Tomhannock Creek, Rensselaer Co., N.Y. (75). | 15 | 15 |
| 64 | 1864, April 12 | Nerft, Kurland, Russia (44). | 48 | 48 |
| 65 | 1866, June 9 | Knyahinya, Ungghvar, Hungary (60). | 41 | 65 |
| 66 | 1867, June 9 | Tadjéra, Sétif, Algeria (100). | 44 | 44 |
| 67 | 1868, Jan. 30 | Pultusk (Sielce), Poland (45). | 177 | 394 |
| 68 | 1868, Nov. 27 | Danville, Morgan Co., Alabama (51). | 11 | 11 |
| 69 | 1869, Dec. 5 | Frankfort, Franklin Co., Alabama (46). | 185 | 217 |
| 70 | 1869, found | Near Salt Lake City, Utah (69). | 785 | 785 |
| 71 | 1869, Jan. 1 | Hessle, near Upsala, Sweden (58). | 39 | 39 |
| 72 | 1869, May 5 | Krähenberg, Zweibrücken, Palatinate (50). | 2 | 2 |
| 73 | 1869, May 22 | Cléguérec (Kernouvé), Morbihan, France (47). | 13 | 13 |
| 74 | ca. 1870 | Rockport, Texas (95). | 105 | 105 |
| 75 | 1871, May 21 | Searsmont, Waldo Co., Maine (53). | 10 | 10 |
| 76 | 1872, July 23 | Lancé (Authon), Loir-et-Cher, France (101). | 27 | 27 |
| 77 | 1873, June | Jhung, Punjab, India (72). | 16 | 16 |
| 78 | 1873, Sept. 23 | Khairpur, Bhawalpur, India (85). | 10 | 10 |
| 79 | 1874, found | Wacanda, Mitchell Co., Kansas (62). | 54 | 123 |
| 80 | 1874, May 14 | Castalia, Nash Co., North Carolina (70). | 247 | 247 |
| 81 | 1875, Feb. 12 | Iowa County (Homestead), Iowa (56). | 11,960 | 35,719 |
| 82 | 1876, Dec. 21 | Rochester, Fulton Co., Indiana (58). | 15 | 15 |
| 83 | 1877, Jan. 3 | Warrenton, Warren Co., Missouri (57). | 106 | 260 |
| 84 | 1877, Oct. 13 | Sako-Banja, Sarbanovac, Servia (66). | 2 | 2 |
| 85 | 1878, found | Fayette County (Bluff), Texas (87). | 434 | 774 |
| 86 | 1878, Nov. 20 | Rakovka, Tula, Russia (65). | 0.3 | 0.3 |
| 87 | 1879, July 1 | Nagaya, Entre Rios, Argentina (86). | 4 | 10 |
| 88 | 1882, Feb. 2 | { Baré, Möcs, Transylvania (71a). Möcs, Transylvania (71bc). | 50 104 | 50 123 |
| 89 | 1883, Feb. 16 | Alfianello, Brescia, Italy (73). | 100 | 175 |
| 90 | 1884, Mar. 19 | Djati-Pengilong, Java (88). | 250 | 250 |
| 91 | 1887, found | { Rockwood (Crab Orch'd), Roan Co., Tenn (90a) Powder Mill Cr'k, Cumberland Co., " (90b) | 96 17 | 96 17 |
| 92 | 1887, Aug. 30 | Taborg, Ochansk, Perm, Russia (89). | 10 | 10 |
| 93 | 1887, found | Morristown, Hamblen Co., Tennessee (98). | 114 | 114 |
| 94 | 1887, found | Pipe Creek, Brandena Co., Texas (97). | 49 | 49 |
| 95 | 1888, found | Llano del Inca, Atacama, Chile (91). | 46 | 46 |
| 96 | 1888, found | Doña Inez, Atacama, Chile (92). | 53 | 53 |
| 97 | 1890, May 2 | Winnebago County, Iowa (93). | 3,200 | 27,730 |
| 98 | 1890, June 25 | Farmington, Washington Co., Kansas (94). | 216 | 247 |
| 99 | 1892, Aug. 29 | Bath, South Dakota (96). | 126 | 126 |

METEORIC IRONS.

| | Date of Discovery. | Locality and Catalogue Number. | Weight in grams. | |
|-----|--------------------------------------|---|------------------|--------|
| | | | Largest mass. | Total. |
| 100 | Prehistoric | Turner Mounds, Anderson, Ohio (85). | 6 | 6 |
| 101 | { 1751, fall 1164 1847, fall 1164 | Steinbach, Erzgebirge, Saxony (2). | 1 | 2 |
| | | Rittersgrün, Erzgebirge, Saxony (71). | 23 | 23 |
| 102 | 1811, fall 1400 | Elbogen, Bohemia (7). | 8 | 8 |
| 103 | 1749 | Krasnojarsk, Siberia (3)—"Pallas Iron." | 1,327 | 1,780 |
| 104 | 1751, May 26 fall | Agram, Hraschina, Croatia (1). | 3 | 3 |
| 105 | ante 1776 | Xiquipilco, Toluca, Mexico (4). | 880 | 900 |
| 106 | ante 1776 | Ixtlahuaca, Toluco, Mexico (87). | 992 | 1,883 |
| 107 | ante 1780 | Descubridora, Catorze, San Luis Potosi, Mx. (58). | 195 | 195 |
| 108 | 1784 | Bemdego, Bahia, Brazil (86). | 162 | 162 |
| 109 | 1793 | Cape of Good Hope, South Africa (5). | 8 | 12 |
| 110 | ca. 1807 | Bitburg (Albacher Mühle), Eifel, Prussia (8). | 58 | 63 |
| 111 | 1808 | Red River, Texas (6). | 740 kil | os |
| 112 | 1810 | Tocavita (Santa Rosa), Colombia, S. A. (78). | 2 | 2 |
| 113 | — | Colombia, South America (51). | 57 | 57 |
| 114 | 1814 | Lenarto, Saros, Hungary (9). | 120 | 120 |
| 115 | 1818 | Lockport (Cambria), New York (10). | 2,715 | 2,715 |
| 116 | ante 1819 | Burlington, Otsego Co., New York (11). | 738 | 738 |
| 117 | 1820 | Guilford County, North Carolina (12). | 20 | 20 |
| 118 | 1822 | Imilac, Atacama Desert, Chile (13). | 178 | 278 |
| 119 | 1827 | Newstead, Roxburghshire, Scotland (44). | 96 | 96 |
| 120 | 1827 | Sanchez Estate, Santa Rosa, Coahuila (84). | 380 | 380 |
| 121 | 1829 | Bohumilitz, Prachin. Bohemia (14). | 37 | 37 |
| 122 | 1832 | Walker County, Alabama (23). | 350 | 354 |
| 123 | 1834 | Claiborne (Lime Creek), Alabama (15). | 64 | 64 |
| 124 | 1834 | Scriba, Oswego County, New York (19). | 173 | 173 |
| 125 | 1835, Aug. 1 fall | Charlotte, Dickson County, Tennessee (38). | 2 | 2 |
| 126 | ante 1836 | Wichita County (Brazos River), Texas (89). | 167 | 169 |
| 127 | 1837 | Coahuila, Bolson de Mapini, Mexico (64). | 1,508 | 2,810 |
| 128 | — | Chihuahua, Mexico (49). | 51 | 51 |
| 129 | 1839 | Putnam County, Georgia (16) | 294 | 380 |
| 130 | ante 1840 | Cosby's Creek, Cooke Co., Tennessee (17). | 934 | 977 |
| 131 | 1840 | Arva (Magura), Hungary (18). | 826 | 1,126 |
| 132 | 1840 | Tarapaca, Hemalga, Chile (76). | 17 | 17 |
| 133 | ca. 1844 | Carthage (Coney Fork), Tennessee (24). | 104 | 104 |
| 134 | ante 1845 | Carysfort, De Calb Co., Tennessee (21). | 61 | 61 |
| 135 | 1845 | Saint Augustine's Bay, Madagascar (22). | 7 | 7 |
| 136 | 1846 | Netschaëvo, Tula, Russia (69). | 31 | 31 |
| 137 | ante 1847 | Seeläsgen, Brandenburg, Prussia (25). | 174 | 174 |
| 138 | 1847, July 14 fall | Braunau (Hauptmannsdorf), Bohemia (90). | 10 | 11 |
| 139 | ante 1849 | Chesterville, Chester Co., So. Carolina (27). | 758 | 758 |
| 140 | ante 1850 | Pittsburg, Pennsylvania (26). | 213 | 213 |
| 141 | ante 1850 | Salt River, Kentucky (29). | 985 | 985 |
| 142 | ante 1850 | Ruff's Mountain, Lexington Co., N. C. (30). | 536 | 536 |
| 143 | 1850 | Schwetz, Prussia (28). | 256 | 256 |
| 144 | 1851 | Seneca Falls, Cayuga Co., New York (31). | 378 | 378 |
| 145 | ante 1851 | Tucson, Arizona, "Signet Iron" (83). | 205 | 205 |
| 146 | ante 1851 | Tucson, Arizona, "Carleton Iron" (37). | 158 | 158 |
| 147 | 1852 | Poplar Hill, Cranberry Plains, Va. (62). | 21 | 21 |
| 148 | ante 1853 | Lion River, Gt. Namaqualand, So. Africa (33). | 40 | 40 |
| 149 | 1853 | Tazewell, Claiborne Co., Tennessee (34). | 418 | 418 |
| 150 | 1853 | Union County, Georgia (65). | 15 | 15 |
| 151 | 1854, 1873 | Jewell Hill (Duel Hill), Madison Co., N. C. (41). | 5,610 | 5,676 |
| 152 | 1854 | Octibbeha County, Mississippi (36). | 1 | 1 |
| 153 | 1854 | Madoc, Ontario, Canada (35). | 26 | 26 |

METEORIC IRONS—*Continued.*

| | Date of Discovery. | Locality and Catalogue Number. | Weight in grams. | |
|-----|--------------------|---|------------------|---------|
| | | | Largest mass. | Total. |
| 154 | 1854 | Cranbourne, Victoria, Australia (56). | 103 | 103 |
| 155 | <i>ante</i> 1856 | Orange River, South Africa (39). | 27 | 27 |
| 156 | 1856 | Denton County, Texas (42). | 66 | 66 |
| 157 | 1856 | Fort Pierre, South Dakota (43). | 343 | 343 |
| 158 | 1856 | Hainholtz, Minden, Westphalia (38). | 8 | 8 |
| 159 | 1858 | Augusta County (Stanton), Virginia (77). | 885 | 885 |
| 160 | 1858 | Trenton, Washington Co., Wisconsin (57). | 65 | 113 |
| 161 | 1860 | Nelson County, Kentucky (40). | 112 | 112 |
| 162 | 1860 | Lagrange, Oldham Co., Kentucky (60). | 46 | 46 |
| 163 | 1860 | Coopertown, Robertson Co., Tennessee (45). | 115 | 115 |
| 164 | <i>ante</i> 1861 | Sierra de Chaca (Vaca Muerta), Atacama (72). | 40 | 40 |
| 165 | 1862 | Colorado River, La Paz, New Mexico (46). | 11 | 11 |
| 166 | <i>ante</i> 1863 | Southeast Missouri (47). | 68 | 68 |
| 167 | <i>ante</i> 1863 | Dakota (48). | 4 | 4 |
| 168 | 1863 | Russell Gulch, Gilpin Co., Colorado (55). | 126 | 126 |
| 169 | 1863 | Obernkirchen, Schaumburg-Lippe, Ger. (91). | 89 | 89 |
| 170 | 1863, fall | Nejed, Central Arabia (92). | 30 | 30 |
| 171 | 1866 | Bear Creek, Denver, Colorado (53). | 151 | 157 |
| 172 | 1866 | Frankfort, Franklin Co., Kentucky (54). | 37 | 37 |
| 173 | 1867 | Arizona, exact locality unknown (52). | 31 | 31 |
| 174 | 1867 | Scotsville, Allen Co., Kentucky (80). | 41 | 74 |
| 175 | 1868 | Losttown, Cherokee Co., Georgia (93). | 3 | 3 |
| 176 | 1869-70 | Shingle Springs, Eldorado Co., Cal. (59). | 603 | 635 |
| 177 | 1872 | Nenntmannsdorf, Pirna, Saxony (66). | 47 | 47 |
| 178 | <i>ante</i> 1875 | Butler, Bates Co., Missouri (73). | 970 | 970 |
| 179 | 1875 | Santa Catarina (Morro do Ricio), Brazil (67). | 720 | 1,661 |
| 180 | 1877 | Dalton, Whitfield Co., Georgia (94). | 33 | 33 |
| 181 | 1879, May 10 fall | Estherville, Emmet Co., Iowa (74). | 41,960 | 48,175 |
| 182 | 1880 | Ivanpah, San Bernardino Co., Cal. (70). | 4 | 4 |
| 183 | 1880 | Lexington Co., South Carolina (68). | 49 | 49 |
| 184 | 1880 | Eagle Station, Carroll Co., Kentucky (95). | 70 | 70 |
| 185 | 1882 | Hex River Mts., Cape Colony, S. Africa (108). | 46 | 46 |
| 186 | 1883 | Grand Rapids, Michigan (82). | 638 | 678 |
| 187 | 1883 | Hammond, St. Croix Co., Wisconsin (96). | 22,730 | 23,640 |
| 188 | 1883 | Plymouth, Indiana (105). | 111 | 111 |
| 189 | 1884 | Puquios, Chile (110). | 24 | 24 |
| 190 | 1884 | Glorieta Mt., Santa Fe Co., New Mexico (79). | 2,840 | 3,970 |
| 191 | 1884 | Independence Co. (Joe Wright Mt.), Ark. (97). | 103 | 103 |
| 192 | <i>ca.</i> 1886 | Kiowa County, Kansas (102). | 46,137 | 46,137 |
| 193 | 1886 | Thunda, Queensland, Australia (106). | 64 | 64 |
| 194 | 1887 | Silver Crown, Laramie Co., Wyoming (109). | 46 | 46 |
| 195 | <i>ante</i> 1888 | Bella Roca, Durango, México (99). | 332 | 332 |
| 196 | 1888 | Hamilton Co., Texas (100). | 173 | 173 |
| 197 | 1888 | Welland, Ontario, Canada (104). | 58 | 58 |
| 198 | <i>ante</i> 1889 | Kenton Co. (Independence), Kentucky (101). | 5,698 | 5,698 |
| 199 | 1890 | Bridgewater Station, Burke Co., N. C. (107). | 19 | 19 |
| 200 | 1891 | Cañon Diablo, Arizona (103). | 375,450 | 383,000 |
| 201 | 1894 | Cherokee Mills, Georgia (111). | 89 | 89 |

The last catalogue of the meteorites preserved in the Mineralogical Collection of Yale University was published in 1886. At that time the total number of catalogued specimens, both stones and irons, amounted to 147, an increase of 45 over the last previous catalogue of 1869. At the present time (1896) the total number of falls represented is 201, an increase of 37 per cent. The total weight of the stones is about 100 kilos, of the irons 1274 kilos, in all 1374 kilos (about 3025 pounds), an increase of 53 per cent.

The largest specimen in the collection is still the well known iron from Red River, Texas, which weighs 740 kilos (1,635 lbs.). The next largest is a fine mass of the Cañon Diablo, Arizona, iron, which weighs 375 kilos (826 lbs.). This was presented to the collection as a memorial of Prof. Elias Loomis by his sons and friends. Another large mass is that of the Kiowa County, Kansas, a pallasite, which weighs 46 kilos (102 lbs.). This is one of a number discovered about 1886; it was presented by E. M. Reed and Pierce N. Welch. A notable mass, also, is that discovered in 1883 at Hammond, St. Croix County, Wisconsin, which was presented by Prof. H. A. Newton. This weighed originally some 25 kilos (55 lbs.), but pieces have been cut off for purposes of exchange, the large mass at present weighing 23 kilos (50.6 lbs.). In the present catalogue the fall of May 10, 1879, in Emmet County, Iowa, is classed among the irons. Representing this fall are nearly six hundred complete specimens, the largest weighing 42 kilos (nearly 100 lbs.), the smaller ranging from those weighing a pound down to those of the size of a pea. Among the irons may also be mentioned a small slice of the meteoric iron which was found in 1883 on the altar of one of the "Turner" Indian mounds, in the Little Miami Valley, Ohio. This was presented by Prof. H. A. Newton. It has since been shown that these fragments are probably derived from masses of the Kiowa County fall just mentioned.

Among the stones the most important addition is the collection from the fall of May 2, 1890, in Winnebago County, Iowa, which was presented by Henry K. and Alice F. English. This collection numbers between 900 and 1,000 separate stones, most of them perfect, and is one of the largest collections from a single fall that exists in any museum. Another notable fall is that of Feb. 12, 1875, in Iowa County, Iowa, which contains 20 stones, eight of them weighing more than a kilo, and the largest weighing about 12 kilos. Other large stones in the collection are those of Weston, Connecticut; Guernsey Co., Ohio; Cape Girardeau, Missouri; and Salt Lake City, Utah. A slice of the interesting stone which fell March 19, 1884, at Djati-Pengilong, Java, which was presented by the Dutch government, may also be mentioned.

It is desired to increase the collection as opportunity offers and to make it as complete as possible. Any communication having this end in view, either by gift, purchase or exchange, may be addressed to Prof. E. S. Dana, Curator of the Collection, at New Haven, Conn.

HENRY S. WASHINGTON.

June, 1896.

NOTE.—The last list of the meteorites in the British Museum by L. Fletcher has been in general followed in the preparation of this Catalogue. Since its completion the list of the Vienna collection by Brezina has been received. It should be noted that Brezina shows that the irons of Jewell Hill (1854) and of "Duel Hill" (No. 151 above) are probably distinct.

Marvelous Missouri Calcites



Our own wonderful collections of last spring, which included by far the finest yellow Calcites ever found up to that time, are surpassed by the more recent finds. Our collector has been in Joplin for nearly two months and we have, therefore, received the best specimens the district has yielded. Rich golden tipped Calcites with many planes, extra fine combinations of purple, smoky and yellow Calcites, showing six bright terminal planes; twins, groups, single crystals; Calcites large and small, 10c. to \$5.00.

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[FOURTH SERIES.]

ART. VIII.—*Outline of a Natural Classification of the Trilobites*; by CHARLES E. BEECHER. (With Plate III.)

Introduction.

WITH the possible exception of the barnacles, no group of arthropods has received more varied treatment by specialists than the trilobites. This taxonomic uncertainty has been due mainly to a lack of knowledge of the structure, and to certain real or fancied resemblances to *Limulus*.

The early references of trilobites to the mollusks, insects, and fishes need not be noticed, for since they have been made the subject of special study, they have been commonly classed with the crustacea, and placed near the phyllopods by most observers. Quite a number of naturalists, however, still divorce the trilobites and limuloids from the crustacea and ally them with the arachnids. It is not proposed at this time to discuss the homologies of *Limulus*, but the trilobites show the clearest evidence of primitive crustacean affinities, in their protonauplius larval form, their hypostoma and metastoma, the five pairs of cephalic appendages, the slender jointed antennules, the biramous character of all the other limbs and their original phyllopodiform structure. They differ from *Limulus*, not only in most of these regards, but also in not having an operculum. From this and all other arthropods, they are distinguished by having compound eyes on free cheek pieces which apparently represent the pleura of a head segment that is otherwise lost, except possibly in some forms of stalked eyes and in the cephalic neuromeres of later forms. The most recent discussions as to the affinities of trilobites are to be found in the papers by Bernard,^{7, 8, 9, 10} Kingsley,²³ Woodward,³⁴ and the

writer,⁵ where from the facts presented, their intimate relationships with the crustacea follow as a necessary corollary.

Previous Classifications.

The various schemes of classification that have been applied to the trilobites since that of Brongniart,¹¹ in 1822, have been enlarged and revised by various authors, until, at the present time, no particular arrangement of the families or genera can be said to be endorsed. The one which is generally recognized as manifestly faulty, that of Barrande,³ is the one most commonly found in text-books and special memoirs. Barrande's definitions and limitations of the generic and family groups were natural and accurate, showing a most complete knowledge of generic and specific values, but in the grouping and arrangement of the families, he selected characters of secondary rank.

Of all the investigators who have attempted any classification of the families, J. W. Salter²² seems to have had the clearest insight into the important value of certain characters, and to have approached nearest to a natural system. In zoölogical research, the study of ontogeny and the principles of morphogenesis were then scarcely recognized as having any direct application. It is quite remarkable, therefore, that Salter, as early as 1864, should have singled out, as the basis of his subdivisions, the characters which are the dominant variants in ontogeny.

It is not necessary in this place to discuss all the classifications which have been proposed. Barrande³ gives a complete resumé down to 1850, and shows in a very satisfactory manner the weak points of each, furnishing strong reasons as to why they are unnatural and therefore untenable. The underlying principles of these early attempts at a classification are here briefly summarized. (1) The first classification of trilobites was advanced by Brongniart¹¹ in 1822, in which all the forms previously known as *Entomolithus paradoxus* were shown to belong to five distinct genera. (2) Dalman,¹⁶ in 1826, made two groups based upon the presence or absence of eyes. (3) Quenstedt,³⁰ in 1837, recognized the number of thoracic segments and the structure of the eyes as of the greatest importance. (4) Milne-Edwards,²⁸ in 1840, considered the power of enrollment as of prime value. (5) Goldfuss,²⁰ in 1843, made three groups, depending on the presence or absence of eyes and their structure. (6) Burmeister,¹² in 1843, accepted the two divisions of Milne-Edwards, and laid stress on the nature of the pleura and the size of the pygidium. (7) Emmrich's first scheme,¹⁷ in 1839, was founded on the shape of the pleura, the presence or absence of eyes and their structure. (8) The later classification of the same author,¹⁸ published in 1844, was

based on whether the abdomen was composed of fused or free segments, and the minor divisions depended chiefly on the structure of the eyes and the facial suture. (9) Corda,¹⁵ in 1847, placed all trilobites in two groups, one having an entire pygidial margin, and the other with the pygidium lobed or denticulate. (10) McCoy,²⁵ in 1849, took the presence or absence of a facet on the pleura for a divisional character. As this is an indication of the power or the inability of enrollment, it does not differ materially from the schemes of Milne-Edwards and Burmeister.

Zittel,²⁵ in a historical review brought down to 1885, includes in addition the schemes of Barrande and Salter, and remarks that the basis of Barrande's general grouping, namely, the structure of the pleura, has neither a high physiological nor morphological meaning. Both Barrande and Salter recognize nearly the same families, with slight differences, and the latter adopts a division into two lines, based on the number of body rings and the size of the pygidium. These include and are themselves included in four groups, founded on the presence and form of the facial suture and the structure of the eyes.

Haeckel* has recently given the trilobites their full value in a classification of the articulates. Although he has not advanced a detailed classification, still it is desirable to review the ordinal groups which he proposes. He considers the *Trilobita* as a legion under the first class, *Aspidonia*, of the crustacea, which is characterized as being without a nauplius larval form and as having a pair of preoral antennæ. In this class is also included the legion *Merostomata*, the *Trilobita* being especially distinguished by the number and character of the legs. The writer³ believes that it is now satisfactorily demonstrated that the protaspis, or early larval form of the trilobite, is a protonauplius, and homologous with the nauplius of higher crustacea. Therefore, the *Trilobita* cannot remain in the *Aspidonia* as here defined.

Haeckel further divides the *Trilobita* into two orders, the first, the *Archiaspides* (or *Protrilobita*), and the second, the *Eutrilobita* (or *Pygidiata*). The *Archiaspides* is represented by the families Olenida and Triarthrida, and is distinguished by the absence of a real pygidium, and by the complete homonomy of the numerous body segments and their phyllopodiform appendages. The families are themselves distinguished by the semicircular or crescent-shaped cephalon and by the presence or absence of genal spines. The *Eutrilobita* is represented by the families Asaphida and Calymenida, and is marked by the heteronomy of the body segments as expressed in the functional pygidium.

* Systematische Phylogenie der wirbellosen Thiere (Invertebrata). Zweiter Theil. 1896.

Salter, Burmeister, and Emmrich have, as previously noticed, attempted to use the comparative size and development of the pygidium for dividing the trilobites into groups larger than families, and it seems evident from the present state of knowledge that it is impossible to make this character of more than family or even generic value. Many of the genera which must naturally be included in the *Archiaspida* have pygidia that cannot be said to be rudimentary, obsolete, or wanting in function. Even those genera having pygidia with few segments, as *Mesonacis*, *Holmia*, *Paradoxides*, *Selenopeltis*, *Dicranurus*, *Bronteus*, *Harpes*, etc., show in many other more important characters that they are highly differentiated and specialized forms and that this feature is one expression of such development. The futility of the scheme is at once evident when a comparison is made between allied genera which present marked differences in the size and segmentation of the pygidium, as *Phacops* and *Dalmanites*, *Ceraurus* and *Encrinurus*, *Calymene* and *Homolanotus*, *Harpes* and *Trinucleus*, *Mesonacis* and *Zecanthoides*, *Paradoxides* and *Dikelocephalus*.

The last classification to be noticed is that of E. J. Chapman,¹³ in 1889, in which four suborders or primary groups are proposed, differing considerably from any previous arrangement, and based upon arbitrary features of general structure and configuration, especially the form of the glabella, whether wide, conical, or enlarged. Twenty-seven families are recognized. In this scheme, *Trinucleus*, *Ampyæ*, and *Æglina* form one section; *Paradoxides* and *Acidaspis*, together with *Phacops* and *Encrinurus*, another; all under one suborder. Omitting the Agnostidæ, there are here considered in a single suborder the most characteristic representatives of nearly all the types of trilobite structure. *Proëtus*, *Cyphaspis*, and *Arethusina* fall into three sections, under two suborders, although these genera, on account of their great similarity in essential points, are placed in a single family by most authors. A further analysis of this classification in its broader lines would be unprofitable. It is sufficient to state that the facts obtained from the study of the ontogeny of any species are completely in discordance with these classifications, and clearly demand other interpretations.

Rank of the Trilobites.

As to the rank of the trilobites in a classification of the crustacea, there is also much diversity of opinion. They have long been regarded as an order, but any attempt to include them in this way under higher groups, such as the *Entomostraca*, *Malacostraca*, or *Palæocarida*, results in such broad generalities and looseness of definition as to render these divisions of little

value. Even the *Entomostraca*, as restricted to the orders Phyllopoda, Ostracoda, Copepoda, and Cirripedia, seems heterogeneous and probably polyphyletic. Milne-Edwards,²⁷ Gegenbaur,¹⁹ Walcott,³³ and others have considered the trilobites as belonging to a class of arthropods intermediate between the crustacea and arachnids. Some recent authors, as Lang,²⁴ have attempted to overcome the difficulty by attaching them as an appendage ("Anhang") to the crustacea. Kingsley,²³ on the other hand, has placed them as a subclass of the crustacea, leaving all the other crustacea to come under a second subclass, the *Eucrustacea*. The present state of knowledge of their structure and development is in favor of giving the trilobites the rank of a subclass, but for purposes of comparison and correlation, the fullest results can be brought out by recognizing the old and well-known subclasses,—the *Entomostraca* and *Malacostraca*.

The following tabular view of the leading points of the comparative morphology of the three subclasses is introduced to show, first, the claims of the *Trilobita* as an equivalent group, and, second, the progressive differentiation of characters. In nearly every particular the trilobite is very primitive, and closely agrees with the theoretical crustacean ancestor. Its affinities are with both the other subclasses, especially their lower orders, but its position is not intermediate.

Comparative Morphology of Crustacea.

| Subclass I. <i>Trilobita</i> . | Subclass II. <i>Entomostraca</i> . | Subclass III. <i>Malacostraca</i> . |
|--|---|---|
| 1. All marine. | Marine and fresh water. | Marine and fresh water. |
| 2. Free. | Free, parasitic, and attached. | Free and parasitic. |
| 3. Body longitudinally triregional. | Various. | Various. |
| 4. Larva a protonauplius. | Larva almost universally a nauplius. | Larva generally a zoea, a nauplius stage being often developed before hatching, except in <i>Euphausia</i> and <i>Peneus</i> . |
| 5. Number of segments variable. | Number of segments variable. | Definite number of segments. |
| 6. Cranium of five fused segments. | Head of five fused segments to which, rarely, a thoracic segment is added. | Head of five fused segments to which one or more, or all of the thoracic segments may unite, forming a more or less complete cephalothorax. |
| 7. Ocelli rarely present. | Ocelli present throughout life. | Ocelli absent in adult forms. |
| 8. Paired compound sessile eyes on cheek pieces usually present. | Paired compound eyes usually present; stalked or sessile. Absent in adult Cirripedia and some Copepoda. | Paired compound eyes usually present; stalked or sessile. |

| Subclass I. <i>Trilobita.</i> | Subclass II. <i>Entomostraca.</i> | Subclass III. <i>Malacostraca.</i> |
|---|--|---|
| 9. Thorax distinct; number of segments variable, all free. | Thorax with variable number of segments. | Thorax with eight segments, some of which are generally united with the head. |
| 10. Abdomen distinct; variable number of fused segments. | Abdomen with variable number of separate segments. | Abdomen of seven generally free segments; eight in <i>Leptostraca</i> . |
| 11. All segments of cranium, thorax, and abdomen, except the anal segment, carry paired appendages | Some segments without appendages. | All segments usually carry appendages except the last one or two. |
| 12. All appendages biramous except antennules | Some appendages are modified and have lost biramous structure. | Some appendages have lost biramous structure. |
| 13. Appendages typically phyllopodiform. Exopodite a swimming leg; endopodite modified into a crawling leg. | Appendages generally greatly changed in most orders; phyllopodiform in young forms, and throughout life in Phyllopoda. | Appendages typically phyllopodiform, but greatly modified in all but the lowest order (<i>Nebalia</i>). |
| 14. All appendages of the head except antennules pediform. | Some appendages of the head modified into rowing organs, mandibles, or suckers. | Some appendages of the head modified into mandibles, or organs for seizing food. |
| 15. Thoracic appendages ambulatory and swimming. | Thoracic appendages ambulatory, swimming, and seizing. | Thoracic appendages ambulatory, swimming, and seizing. |
| 16. Abdominal limbs on all segments except the anal, phyllopodiform. | Abdominal limbs generally wanting. | Abdominal limbs often reduced except the last pair, which with telson frequently form a caudal fin. Chiefly branchial in some groups. |
| 17. Coxal elements of all limbs forming gnathobases, which become manducatory organs on the head. | Coxal elements seldom forming gnathobases except on the head. | Coxal elements seldom forming gnathobases except on the head; never on the abdomen. |
| 18. Respiration cuticular and by fringes on exopodites. | Respiration mainly cuticular and by the limbs and gill appendages. | Respiration cuticular and by the limbs and epipodites. |

The more primitive characters of the trilobites as drawn from the foregoing table may be summarized as follows: (1) They are all free marine animals; (2) the animal has a definite configuration; (3) the larva is a proto-nauplius-like form; (4) the body and abdomen are richly segmented, and the number of segments is variable; (5) the head corresponds to the typical crustacean; (6) the thorax and abdomen are always distinct, the number of segments in each being variable; (7) all segments except the anal bear paired appendages; (8) all appendages are typically phyllopodiform; and (10) the coxal elements of all limbs form gnathobases, which become organs of manducation on the head.

It may be questioned by some whether the present state of knowledge of the ventral structure of trilobites warrants such general assertions as to details of organization. In the first place, it must be granted that there is a remarkable uniformity in the features of the dorsal crust, which naturally reflects to a degree the differentiation and variation of the organs and appendages of the ventral side. Furthermore, the actual appendages have been observed in such diverse and characteristic genera as *Trinucleus*, *Triarthrus*, *Asaphus*, *Ceraurus*, and *Calymene*, and found to conform closely to a single type, so that it seems safe to assume a like agreement throughout.

Morphology of the Cephalon.

The structure of the trilobite head suggests homologies which should be noticed here, and if these correlations are based upon true structural likenesses, they serve not only to emphasize the primitive character of the trilobite, but also aid in interpreting certain organs and structures in the higher crustacea.

The five fused somites of the crustacean head are generally believed to correspond to the third, fourth, fifth, sixth, and seventh neuromeres, leaving the first and second unrepresented either by distinct segments or appendages. These two neuromeres commonly constitute most of the cerebral mass above the œsophagus, and enervate the ocelli and paired eyes. In some, the antennæ are enervated from supra-œsophageal ganglia, while in other forms their ganglia are infra-œsophageal. It was formerly supposed that the stalked eyes of the higher crustacea represented appendages of a head segment, but this belief has been abandoned on account of the derivation of stalked out of sessile organs, as in *Peneus*, and also because the eyes do not always have a relatively fixed position, but may pertain to the first, second, or third head segments. Their structural position in the trilobites, however, is invariable, and it seems probable that in some families of higher crustacea, the eyes are in exact correlation, and may be similarly interpreted.

The writer⁶ has previously discussed this question, and adduced reasons for considering the free cheeks in trilobites as "the pleura of an oculiferous head segment." In many species (*Dalmanites*, *Æglina*, etc.), the free cheeks are continuous, forming one piece extending around the front of the head, between the cranidium and the hypostoma, while in others there is a separate piece, the epistoma, between the proximal ends of the cheek pieces holding a like position. These structures occupy the exact position of a true segment, and since, upon theoretical grounds, additional head segments

are to be accounted for, the only satisfactory correlation is to consider them as such. Furthermore, the free cheeks are distinctly separated from the cranium by an open suture, and may be wholly converted into eyes, as in *Eglina armata* Barr., or the unfaceted portion may be reduced to almost nothing, as in *Deiphon*. In such cases, the parallelism is exact with true movable eyes. Bernard⁷ concludes from his studies of *Apus* that the hypostoma is homologous with the annelid prostomium. This would make the hypostoma represent the first, and the free cheeks the second of the obsolete segments. Thus the trilobite cephalon would fulfil the demand for additional evidences of primitive head segments, and account for the development of eyes separate from the cephalothorax as commonly restricted.

Supposed evidences of free cheeks or of facial sutures have been recognized in *Limulus*, *Hemiaspis*, and *Bunodes*, but these seem really to correspond to the lines on the dorsal surface of the cephalon of *Harpes* and some *Trinucleus*, running from the glabella to the eye spots and to the margin, and are not the sutures marking the limits of the free cephalic elements, as in *Asaphus* and *Proetus*. *Limulus*, however, has a suture comparable to that in *Harpes* and *Trinucleus*, extending around the ventral border of the cephalothorax nearly to the posterior angles, and partly separating the ventral plate. In the process of moulting, this suture opens and enables the animal to free itself from its former test.

These interpretations may be employed to some advantage in correlating the segmentation of the trilobite cephalon. As previously stated, the recognized plan in the nervous system of a generalized crustacean requires that there should be a brain or supra-oesophageal ganglion enervating (a) the unpaired eye, (b) the frontal sensory organs and stalked eyes, and (c) the anterior antennæ; then a ventral nervous chord consisting of a succession of double ganglia enervating, respectively, the second pair of antennæ, the mandibles, the first pair of maxillæ, the second pair of maxillæ, and lastly each of the paired thoracic and abdominal appendages. Altogether, there are seven neuromeres pertaining to the head, and on the basis that each neuromere corresponds to an original segment, as on the post-cephalic region, there would need to be this number accounted for. The anterior segment, or number one in the trilobites, would be represented by the hypostoma; the second segment, by the paired eyes, free cheeks, and epistoma; the third, by the anterior lobe of the glabella and the first antennæ; the fourth, by the second lobe of the glabella and the second pair of antennæ; the fifth, by the third lobe of the glabella and the mandibles; the sixth, by the fourth lobe of the glabella

and the first maxillæ; and the seventh, by the neck lobe, or occipital ring, and the second pair of maxillæ. The five annulations, or lobes, of the axis of the cranium, since they primarily carry fulcra for the attachment of muscles supporting or moving the appendages, could thus be interpreted in terms of the ventral structure, making the first lobe the antennary, the second the antennary, the third the mandibular, the fourth the first maxillary, and the fifth the second maxillary.

No other group of crustacea furnishes such constant and well-developed structures representing the second theoretical head segment, which is obscure or obsolete in all the living groups, excepting probably the stalked eyes of some crustacea and the movable ocular segment of the Stomatopods. For this reason, in addition to the many other important differences previously noted in the table of comparative morphology, the trilobites are regarded as a subclass, and the relative denomination and structural relations of this second segment, along with other characters, are considered as of sufficient physiological and morphological importance to determine the ordinal divisions.

Principles of a Natural Classification.

Most satisfactory and conclusive results have already come from the application of the law of morphogenesis, or the recapitulation theory, to various groups of animals, by means of which their natural classification and phylogenetic relations have been determined. Hyatt²¹ says on this point (1889): "We have endeavored to demonstrate that a natural classification may be made by means of a system of analysis in which the individual is the unit of comparison, because its life in all its phases, morphological and physiological, healthy or pathological, embryo, larva, adolescent, and old (ontogeny), correlates with the morphological and physiological history of the group to which it belongs (phylogeny)." It is also interesting to note that Agassiz¹ recognized in ontogeny a standard of classification. One of his strongest statements is as follows: "Embryology [=ontogeny] will in the end furnish us with the means of recognizing the true affinities among all animals, and of ascertaining their relative standing and normal position in their respective classes with the utmost degree of accuracy and precision."

These principles can be best applied in a group of animals which has a geological history more or less complete, and which is not wholly parasitic or greatly degenerated. It is of the greatest importance, also, to study the ontogeny of primitive and non-specialized species, because without very complete paleontological evidence, the development of a much later

derived form may be so involved with larval adaptations and accelerated characters as to be misleading.

The trilobites lend themselves to this treatment in fulfilling most of the necessary conditions. They have a known geological history stretching through the entire paleozoic, from the beginning of the Cambrian to the Permian. Their structure is generalized and quite uniform, and no sessile, attached, parasitic, land or fresh water species are known. The ontogeny of all the principal groups has been studied, including Cambrian, Ordovician, Silurian, and Devonian types.

The trilobites necessarily furnish little information of the stages of growth which may be classed as embryonic. The early embryonic stages are not preserved as fossils, and therefore may be omitted. In this category are the *protembryo*, or the ovum in its unsegmented and segmented stages (the so-called "eggs of trilobites" may of course represent any stage of embryonic development before the escape of the young); the *mesembryo*, or blastosphere; the *metembryo*, or gastrula; the *neoembryo*, or planula-like stage; and the *typembryo*, when the first distinctive features make their appearance. The first embryonic stage recognized in the trilobites can be referred to the *phylembryo* as defined by Jackson,²² when the animal may be clearly referred to its proper class. Since this period is distinctive for each class of animals and usually bears a separate name, it has been termed by the writer²³ the *protaspis* stage of trilobites. It closely approximates the protonauplius form, or the theoretical, primitive, ancestral larval form of the crustacea. Like the homologous nauplius of modern higher crustacea, it is the characteristic larval type common to the class. The nauplius is therefore considered as a derived larva modified by adaptation.

The post-embryonic stages of ontogeny have received the names *nepionic*, for the infantile or young; *neanic*, for the immature or adolescent; *ephebic*, for the mature or adult; and *gerontic*, for the senile or old. When especially applied to trilobites, the nepionic stages may include the animal when the cephalon and pygidium are distinct and the thorax incomplete. There would thus be as many nepionic stages as the number of thoracic segments. The neanic stages would be represented by the animal with all parts complete, but with the average growth incomplete. Final progressive growth and development of the individual would fall under the ephebic stage. Lastly, general evidences of senility would be interpreted as belonging to the gerontic stage.

Application of Principles for Ordinal Divisions.

In other classes of animals above the lower cœlenterates, the phylembryonic stage is the starting point from which correlations are made, and out of which all the higher groups are developed by a series of changes along certain lines. The protoconch represents this period in the cephalopods and gastropods; the prodissoconch, in the pelecypods; the protegulum, in the brachiopods, and the protechinus, in the echinoids. In the trilobites, the protaspis, as already stated, has the value of the phylembryo, and in its geological history and the metamorphoses it undergoes to produce the perfect trilobite, accurate information can be gained as to what the primitive characters are, and the relative values of other features acquired during the long existence of the class.

The simple characters possessed by the protaspis are the following, as drawn from the study of this stage in all the principal groups of trilobites: Dorsal shield minute, not more than $\frac{1}{4}$ to 1^{mm} in length; circular or ovate in form; axis distinct, more or less strongly annulated, limited by longitudinal grooves; head portion predominating; axis of cranidium with five annulations; abdominal portion usually less than one-third the length of the shield; axis with from one to several annulations; pleural portion smooth or grooved; eyes, when present, anterior, marginal, or submarginal; free cheeks, when visible, narrow and marginal. Examples, Plate III, figs. 1, 5.

During this stage, several moults took place before the complete separation of the pygidium or the introduction of thoracic segments. These brought about various changes, as the stronger annulation of the axis, the appearance of the free cheeks on the dorsal side, and the growth of the pygidium by the introduction of new appendages and segments, as indicated by the additional grooves on the axis and limb. A full representation of the variety and succession of these early protaspis stages is presented in the writer's paper on the "Larval Stages of Trilobites."⁵ Some of the conclusions and discussions in that paper are made use of here.

In the earliest or Cambrian genera, the protaspis stage is by far the simplest expression of this period to be found. In the higher and later genera, the process of acceleration or earlier inheritance has pushed forward certain characters until they appear in the protaspis, thus making it more and more complex.

Taking the early protaspis stages in *Solenopleura*, *Liostracus*, or *Ptychoparia*, it is found that they agree exactly with the foregoing diagnosis in its most elementary sense. Since they are the characters shared in common by all the larvæ at this stage, they are taken as primitive and accorded that value

in dealing with adult forms possessing homologous features. Therefore, any trilobite with a large elongate cephalon, eyes rudimentary or absent, free cheeks ventral or marginal, and glabella long, cylindrical, and with five annulations, would naturally be placed near the beginning of any genetic series or as belonging to a very primitive stock.

Next must be considered the progressive addition of characters during the geological history of the protaspis, and in the ontogeny of the individual during its growth from the larval to the mature condition. It was shown in the paper already referred to, that there was an exact correlation to be made between the geological and zoölogical succession of first larval stages and adult forms, and therefore both may be reviewed together.

The first important structures not especially noticeable in all stages of the protaspis are the free cheeks, which usually manifest themselves in the meta- or para-protaspis stages, though sometimes even later. Since they bear the visual areas of the eyes, when they are present, their appearance on the dorsal shield is practically simultaneous with these organs, and before the eyes have travelled over the margin, the free cheeks must be wholly ventral in position. When first discernible, they are very narrow, and in *Ptychoparia* and *Sao* include the genal angles. In *Dalmanites* and *Cheirurus*, however, the genal angles are borne on the fixed cheeks. If, as Bernard⁷ concludes, the crustacean head has been formed by the bending under, to the ventral side, of the anterior segments of an ancestral carnivorous annelid, this furnishes a means of further determining and also of satisfactorily correlating the prime significance and importance of the free cheeks.

Since the free cheeks are ventral in the earliest larval stages of all but the highest trilobites, and as this is an adult feature among a number of genera which on other grounds are very primitive, this is taken as generally indicative of a very low rank. It seems to mean that the second segment remains where it was mechanically placed, and retains its full somitic nature, though from the necessities of such a condition, true ventral segments must soon disappear through modification into other structures or through disuse as segments. The genera *Harpes*, *Agnostus*, *Trinnucleus*, and their allies agree in having well-developed, continuous, ventral free cheeks, and constitute a natural group. As they possess one expression or type of the genesis of an important common character, based upon facts of development, it should stand as an ordinal character, and as such it is here taken. For this group, the name *Hypoparia* is proposed. It is fully defined, and its limitations established in the proper place in the classification.

The remaining genera of trilobites present two distinct types of head structure, dependent upon the extent and character of the free cheeks. In both, the free cheeks make up an essential part of the dorsal crust of the cephalon, being continued on the ventral side only as a doublure or infolding of the edge, similar to that of the free edge of the cranidium, the ends of the thoracic pleura, and the margin of the pygidium. They may be separated only by the cranidium, as in *Ptychoparia*, or by the cranidium and epistoma, as in *Illænus* and *Homalonus*, or they may be united and continuous in front, as in *Æglina* and *Dalmanites*. One type of structure is distinguished by having the free cheeks include the genal angles, thus cutting off more or less of the pleura of the occipital segment. The genera belonging to this group constitute the second order, the *Opisthoparia*.

The third and last type of structure includes forms in which the pleura of the occipital segment extend the full width of the base of the cephalon, embracing the genal angles. The free cheeks are therefore separated from the cranidium by sutures cutting the lateral margins of the cephalon in front of the genal angles. Genera having this structure are here placed in the order *Proparia*.

Several genera, as *Calymene* and *Triarthrus*, have been described as having the facial sutures beginning at or cutting the apex of the genal angle, thus making it indeterminate whether they should be classed with the *Opisthoparia* or *Proparia*. It will be found, however, that some species of these genera leave no doubt as to the anterior or posterior position of the suture. The small genal spines of *Calymene callicephalæ* Green are situated on the ends of the fixed cheeks, while similar but larger spines in *Triarthrus spinosus* Billings are on the free cheeks, making the former belong to the *Proparia* and the latter to the *Opisthoparia*.

Application of Principles for Arrangement of Families and Genera.

The remaining characters to be noticed have chiefly family and generic values, and naturally follow the preceding discussions. They are of great assistance, both in determining the place of a family in an order, and the rank and genetic position of a genus in a family.

There is very satisfactory evidence that the eyes have migrated from the ventral side, first forward to the margin and then backward over the cephalon to their adult position. The most primitive larvæ should therefore present no evidence of eyes on the dorsal shield. Just such conditions are fulfilled

in the youngest larva of *Ptychoparia*, *Solenopleura*, and *Liostracus*. The eye line is present in the later larval and adolescent stages of these genera, and persists to the adult condition. In *Sao*, it has been pushed forward to the earliest protaspis, and is also found in the two known larval stages of *Triarthrus*. *Sao* retains the eye line throughout life, but in *Triarthrus* the adult has no traces of it. A study of the genera of trilobites shows that this is a very archaic feature, chiefly characteristic of Cambrian genera, and only appearing in the primitive genera of higher and later groups or as an evidence of degeneration. It first develops in the later larval stages of certain genera (*Ptychoparia*, etc.); next in the early larval stages (*Sao*); then disappears from the adult stages (*Triarthrus*); and finally is pushed out of the ontogeny (*Dalmanites*).

In *Ptychoparia*, *Solenopleura*, *Liostracus*, *Sao*, and *Triarthrus*, the eyes are first visible on the margin of the dorsal shield after the protaspis stages have been passed through, and later than the appearance of the eye lines; but in *Proëtus*, *Acidaspis*, *Arges*, and *Dalmanites*, through acceleration, they are present in all the protaspis stages, and persist to the mature or ephebic condition, moving in from the margin to near the sides of the glabella. Progression in these characters may be expressed, and in so far taken for general application among adult forms to indicate rank, as follows: (1) absence of eyes; (2) eye lines; (3) eye lines and marginal eyes; (4) marginal eyes; (5) submarginal eyes; (6) eyes near the pleura of the neck segment.

The changes in the glabella are equally important and interesting. Throughout the larval stages, the axis of the cranium shows distinctly by the annulations that it is composed of five fused segments, indicating the presence of as many paired appendages on the ventral side. In its simplest and most primitive state, it expands in front, joining and forming the anterior margin of the head (larval *Ptychoparia* and *Sao*). During later growth, it becomes rounded in front, and terminates within the margin. In higher genera, through acceleration, it is rounded and well-defined in front, even in the earliest larval stages, and often ends within the margin (larval *Triarthrus* and *Acidaspis*). From these simple types of simple pentamerous glabellæ, all the diverse forms among species of various genera have been derived, through changes affecting any or all the lobes. The modifications usually consist in the progressive obsolescence of the anterior annulations, finally producing a smooth glabella, as in *Illænus* and *Niobe*. The neck segment is the most persistent of all, and is rarely obscured. The third, or mandibular, segment is frequently marked by two entirely separate lateral lobes, as in *Acidaspis*,

Conolichas, *Chasmops*, etc. Likewise, the fourth annulation carrying the first pair of maxillæ is often similarly modified in the same genera, also in all the *Proëtidae*, and in *Cheirurus*, *Crotalocephalus*, *Sphærexochus*, *Ampyx*, *Harpes*, etc. Here again, among adult forms, the stages of progressive differentiation may be taken as indicating the relative rank of the genera.

The comparative areal growth of the free cheeks is expressed by the gradual moving of the facial suture toward the axis. As the free cheeks become larger, the fixed cheeks become smaller. In the most primitive protaspis stages, and in *Agnostus*, *Harpes*, and *Trinucleus*, the dorsal surface of the cephalon is wholly occupied by the axis and the fixed cheeks, while in the higher genera, the area of the fixed cheeks becomes reduced until, as in *Stygina* and *Phillipsia*, they form a mere border to the glabella. Therefore, the ratio between the fixed and free cheeks furnishes another means of assisting in the determination of rank.

The pleura from the segments of the glabella are occasionally visible, as in the young of *Olenellus*, but usually the pleura of the neck segments are the first and only ones to be distinguished on the cephalon, the others being so completely coalesced as to lose all traces of their individuality. The pleura of the pygidium appear soon after the earliest protaspis stage, and in some genera (*Sao*, *Dalmanites*) are even more strongly marked than in the adult state and much resemble separate segments. The growth of the pygidium is very considerable through the protaspis stage. At first, it is less than one-third the length of the dorsal shield, but by successive addition of segments, it soon becomes nearly one-half as long. In some genera, it is completed before the appearance of the free thoracic segments, all of which are added during the nepionic stages. An interpretation of these facts, to apply in valuing adult characters, would indicate that a very few segments, both in thorax and pygidium, may be evidence of arrested development or degeneration. On the other hand, the apparently unlimited multiplication of thoracic and especially of abdominal segments in some genera is also to be considered as a primitive character expressive of an annelidan style of growth. Genera like *Asaphus*, *Phacops*, etc., having a constant number of thoracic segments accompanied by other characters of a high order, undoubtedly represent the normal trilobite type.

These analyses and correlations clearly show that there are characters appearing in the adults of later and higher genera, which successively make their appearance in the protaspis stage, sometimes to the exclusion or modification of structures present in the most primitive larvæ. Thus, the larvæ of *Dal-*

manites or *Proëtus*, with their prominent eyes and glabella distinctly terminated and rounded in front, have characters which do not appear in the larval stages of ancient genera, but which may come in their adult stages. Evidently such modifications have been acquired by the action of the law of earlier inheritance, or tachygenesis.

In a classification of trilobites, for the purpose of illustrating the principles here enunciated, the ontogenies of *Sao* and *Dalmanites*, Plate III, figs. 1–8, are selected. *Sao* belongs to the ancient family Olenidæ of the order Opisthoparia, and naturally may be expected to furnish very clear evidence as to the relations of many lower and older genera. *Dalmanites*, also, with its simple head structure, will give similar data regarding the Proparia.

The early protaspis stage of *Sao*, Plate III, fig. 1, has no dorsal development of the free cheeks, and with the elongate form of the cephalic portion may be compared with the cephalæ of *Agnostus* and *Microdiscus*, and therefore correlates with the Hypoparia. The cephalon, at a later period of development, when the animal has two free thoracic segments, Plate III, fig. 2, shows the narrow marginal free cheeks and distinct eye lines. Here the resemblance to the cephalæ of *Atops* and *Conocoryphe*, Plate III, figs. 14, 15, is very marked, and indicates that the Conocoryphidæ is genetically the first family of the Opisthoparia. When *Sao* has eight thoracic segments, Plate III, fig. 3, the characters of the cephalon accord closely with *Ptychoparia* and *Olenus*, showing that these genera should precede it in arranging the genera of the family Olenidæ. Evidence is thus furnished for the proper position of the first two families of the order. Now, if the relative values of the differentiation of the glabella, the position of the eyes, and the size of the free cheeks are considered in the light of the preceding analyses of these features, the remaining families of the order, as represented in their typical genera, naturally arrange themselves as indicated in Plate III, figs. 18–23. There results (1) the Conocoryphidæ (represented by *Atops* and *Conocoryphe*, figs. 14, 15); (2) the Olenidæ (*Ptychoparia* and *Olenus*, figs. 16, 17); (3) the Asaphidæ (*Asaphus* and *Illænus*, figs. 18, 19); (4) the Proëtidæ (*Proëtus*, fig. 20); (5) the Bronteidæ (*Bronteus*, fig. 21); (6) the Lichadidæ (*Lichas*, fig. 22); and (7) the Acidaspidæ (*Acidaspis*, fig. 23).

For the Proparia, similar results are brought out by the study of the ontogeny of *Dalmanites*, and by comparisons with the characters governing the sequence of families in the Opisthoparia. The narrow marginal free cheeks place the Ecerinuridæ and Calymenidæ as primitive. The small or obsolete eyes and the larval form of the glabella in the former

further show that this family should be placed at the beginning. The nepionic *Dalmanites*, with seven thoracic segments, has a head structure very similar to the adult *Cheirurus* (*Eccoptocheile*), fig. 28, thus making the Cheiruridæ precede the Phacopidæ. The arrangement of families under the Proparia accordingly will be (1) the Encrinuridæ (*Placoparia* and *Encrinurus*, Plate III, figs. 24, 25); (2) the Calymenidæ (*Calymene* and *Dipleura*, figs. 26, 27); (3) the Cheiruridæ (*Cheirurus* (*Eccoptocheile*), fig. 28); and (4) the Phacopidæ (*Dalmanites*, *Chasmops*, *Acaste*, *Phacops*, figs. 29–33).

The sequence of families in the most primitive order, Hypoparia, may now be easily disposed of. The genera are so aberrant and offer such conspicuous differences from ordinary trilobites, that it was considered better to delay their disposition until the variations in structure governing the arrangement of families in the higher orders were clearly shown. The degree of specialization of the glabella, of the form and character of the fixed cheeks, and the great range in the number of segments in the thorax and pygidium are strong evidence that we are dealing with the terminal genera of the order which must have attained its normal development in pre-Cambrian times. *Agnostus* and *Microdiscus* have so many protaspidial and larval characters that they must be considered more primitive than the other genera, although in some respects they show a high degree of specialization and even degeneration, as will be noticed under the family Agnostidæ. Moreover, *Harpes*, in its elongate cephalon, persistent ocelli, and many thoracic segments, is also quite primitive. *Trinucleus*, with ocelli only present in larval stages, a transverse cephalon, and genal spines belonging to the free cheeks, is considerably higher and properly comes last in the order, thus making the arrangement of families as follows: (1) Agnostidæ (*Agnostus*, *Microdiscus*, Plate III, figs. 9, 10); (2) Harpedidæ (*Harpes*, fig. 11); and (3) Trinucleidæ (*Trinucleus*, *Ampyx*, figs. 12, 13).

Diagnoses and Discussions.

Subclass TRILOBITA.

Marine crustacea, with a variable number of metameres; body covered with a hard dorsal shell or crust, longitudinally trilobate from the defined axis and pleura; head, thorax, and abdomen distinct. Head covered with a cephalic shield composed of a primitively pentamerous middle piece, the cranidium, and two side pieces, or free cheeks, which may be

separate or united in front, and carry the compound sessile eyes, when present; cephalic appendages pediform, consisting of five pairs of limbs, all biramous, and functioning as ambulatory and oral organs, except the simple antennules, which are purely sensory. Upper lip forming a well-developed hypostoma; under lip present. Somites of the thorax movable upon one another, varying in number from two to twenty-nine. Abdominal segments variable in number, and fused to form a caudal shield. All segments, thoracic and abdominal, carry a pair of jointed biramous limbs. All limbs have their coxal elements forming gnathobases, which become organs of manducation on the head. Respiration integumental and by branchial fringes on the exopodites. Development proceeding from a protonauplius form, by the progressive addition of segments at successive moults.

Heretofore it has been impossible to give an adequate diagnosis of the *Trilobita*, owing to the absence of information regarding certain important characters, and the obscurity of the information relating to some other features. It is believed that enough is now known to frame a definition of the class, which, in accuracy and completeness, will compare favorably with any based upon living groups. Such a definition brings out the fact that the differences between the trilobites and other large groups are clearly recognizable, and do not consist of a statement of anomalous characters whose real significance is unknown.

[To be continued.]

ART. IX.—*Preliminary Trial of an Interferential Induction balance*; by C. BARUS.

1. THE following device is capable, I believe, of a variety of applications in relation to alternating currents and to magnetic induction. The idea underlying the apparatus is briefly this: Let the slender iron cores of two identical helices be placed at right angles to each other, in the same (horizontal) plane and at like distances from the point of convergence. Let the distant ends of the iron cores be rigidly fastened, while the other ends are free to move (expand and contract) in the direction of the axes. Then it is possible to adapt Michelson's interferential refractor in such a way that the fringes are visible whenever the excursions of the free ends of the cores are either zero or vibrating in the same phase, amplitude and period to and from the point of convergence. The fringes vanish more or less fully for all other phases.

Let the two helices be traversed by the same alternating current, and let the reduced length of the electrical conductor between them be negligible and the vibrations in the same phase initially. Then if the reduced length of the conductor be gradually increased, the two vibrations will be dephased and the fringes will gradually vanish. If the lengthening of the conductor be continued until the excitement of one helix is belated one complete period of the vibrating core with reference to the other, the fringes will reappear *caet. par.* with their original clearness. A method of estimating the speed of signalling from one helix to the other is thus given in terms of the period of longitudinal vibration of the vibrating core.

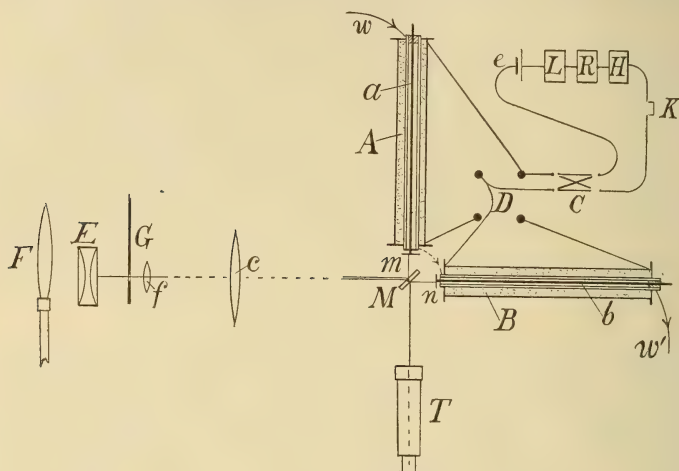
If the helices are not identical, similar deductions apply for the difference of time lag of current behind the electromotive force for the two helices respectively.

Finally vanished fringes are open to observation by stroboscopic methods.

§ 2. The form of apparatus used is shown diagrammatically and largely in sectional plan in the figure. *A* and *B* are the two helices and *a* and *b* their cores of soft Norway iron. These with the helices are rigidly fixed at the further ends. The cores pass axially through the helices without touching them, and carry small light plane mirrors *m* and *n* at their free ends. With the thick plane-parallel plate *M*, these mirrors make up Michelson's refractometer. Light (thus far furnished by a sodium flame) is emitted by the distant burner *F* provided with Cushman's sodium collar,* and condensed by

* This efficient device, due to Holbrook Cushman, consists of a layer of filter paper impregnated with sodium carbonate and wrapped around the top of the burner. The sodium flame so obtained is very dense and lasts for days.

the train of lenses e, f, c . As a rule the flame with a single lens would be sufficient and the train is here given to admit of the introduction of the stroboscopic disc G when an intermittent beam is wanted. Other small fixed screens are often advantageous. Falling on M (preferably covered with a transparent coat of silver), the light undergoes interferential refrac-



tion in the now well-known way. The optical parts of the apparatus are fully described in Michelson's* great memoir, and further reference here is needless. To obtain the interference it is usually sufficient (good glass presupposed) to bring the images of the same small distant luminous point into coincidence. Removing f and c , a small hole in G answers the purposes. If the helix A and its mirror is fixed, the helix B and its mirror must be movable in azimuth and altitude. I found the large round table of an old Kirchhoff spectrometer excellent for this purpose. The helices A and B were mounted in place of the telescopes, and the mirror M on a small adjustable tripod could then be moved on the flat table into position. If the glass is not very good, as is apt to be the case with thin mirrors, m and n , and ordinary plate glass, it is necessary to find the parts of the plates sufficiently plane, by trial. In general it is best to bring the edges of the mirrors to overlap, in which case the interference figure is of lune-shaped outline and relatively clear. The adjustments may be made with the naked eye. For observations, however, the small telescope T ,

* Michelson: *Valeur du Mètre*, Trav. Bureau Int., xi, 1894.

provided with cross-hairs, must be so mounted as to be easily focussed, moved about and inclined.

Whenever a current passes through either of the helices *A* and *B* the cores *a*, *b* will in general expand, unless the field be very intense. Current for this purpose is furnished by one or more storage cells *c*, passes through a commutator *C* and a switch board *D*, by which either one or both the helices may be put into the circuit. The circuit also contains inductive resistance *H*, non-inductive resistance *R* and an interrupter *L* for intermittent currents. *K* is a key. As the magnetic expansion due to complete saturation is only a few millionths, the effects of thermal expansion must be excluded. Hence the frame of each helix is a thin shell-like water-jacket. Water arrives at *w*, passes in a thin sheet between the core and the wire of helix *A*, then similarly through helix *B* and leaves at *w'*. The same temperature is thus obtained for both helices and strong electrical currents passed through them are without thermal effect on the core.

The two helices were wound identically and chiefly for continuous currents. They each consisted of eight layers of No. 21 copper wire with 410 turns in each layer, and they were 37^{cm} long. The diameter of the internal canal was about 0.8^{cm}, and the outer wall of the water-jacket on which the wire was wrapped about 1.5^{cm}. In view of the long helices the enclosed iron cores (about 28^{cm} long, 0.6^{cm} in diameter) were in a fairly constant field.* Their rear ends were soldered into a rod of brass snugly fitting the box of the helix and rigidly fastened by screws. The front ends were soldered to very thin copper tubes which protruded beyond the helix and served as holders for the mirrors *m*, *n*. The cores were made as straight as possible, adjusted symmetrically and coaxially with the helix, leaving a clear space of about 1^{mm} between core and helix. The fastening of the cores is merely suggested in the figure.

When mounted the apparatus must necessarily be placed on a pier or other firm support; but even this is insufficient unless the vibrations are damped at different parts of the apparatus. Thus it is necessary to support the helices from two points near their ends, and independently to prevent transverse vibrations of the core. After many trials I found that a short plug of vasiline in the tubes near the ends *m*, *n* was preferable to mechanical devices. Prof. Mayer's important paper should be consulted on all these points.

§ 3. If both mirrors move towards the point of convergence symmetrically and equally, the same number of wave lengths

* Mayer: Phil. Mag. [4], xlv, p. 177, 1873.

are cut off by both and the interference fringes will not be displaced however fast the mirrors may vibrate. If an appreciable time is spent by the effective current in passing from helix *A* to helix *B*, then with increasing retardation the fringes will gradually vanish and gradually reappear when the time of delay has reached the period of vibration of the mirrors. Let the motion of the mirrors *m*, *n* be given by $a_1 \sin \omega t$ and $a_2 \sin (\omega t + \theta)$. Then the motion of the fringes is proportional to $a' \sin(\omega t - \theta')$; where

$$a' = \sqrt{a_1^2 + a_2^2 - 2a_1a_2 \cos \theta} \text{ and } \tan \theta' = a_2 \sin \theta / (a_1 + a_2 \cos \theta).$$

If the amplitudes are equal

$$a' = 2a \sin \theta / 2 \quad (1)$$

If the self-inductions L_1 and L_2 of the two helices are not equal, if, for instance, the cores are chosen of different diameters, the currents in the helices will lag behind the corresponding electromotive forces by different amounts. The result will bring the interference fringes to vanish more and more fully at first, and finally less and less so, as the difference of self-induction increases, till the dephasing approaches one complete period. If θ_1 and θ_2 be the current lag in each helix and if their ohmic resistance R is the same, then

$$\theta = \theta_1 - \theta_2 = \tan^{-1} \frac{L_1 \omega / R - L_2 \omega / R}{1 + L_1 L_2 \omega^2 / R^2},$$

or

$$\tan \theta = \omega R \frac{L_1 - L_2}{R^2 + L_1 L_2 \omega^2} \quad (2)$$

There are thus two equations, (1) and (2), for θ . If L_2 be made very small $\tan \theta = \omega L_1 / R$. Similar results may be obtained for different amplitudes a_1 and a_2 , and different values for R .

Equation (1), however, may be supposed to include the retardation due to the external resistances as well as the lag in equation (2). From this wider point of view the fringes will be at *rest* if $a' = 0$ or if θ is an even multiple of π . The motion of the interference fringes will be a maximum or they will vibrate to and fro with greatest intensity when θ is an odd multiple of π .

The criterion is, therefore, visibility and clearness of the fringes, and the method of observation is not continuous.

§ 4. With the object of obtaining a continuous series of data the above stroboscopic disc *G* was introduced. It is made of very thin tin plate about 40^{cm} in diameter, with a sufficient

number of equidistant small holes cut near the margin. Mounted on an axle and rotated by a small electromotor, it was supposed that the speed could be regulated nearly enough by inserting resistances. I did not have any success with this disc. Though I was able to increase the flashes to 3000 per second, they were never instantaneous enough for the work, even when the holes were reduced to an extreme of smallness. It ought not to be difficult, however, to reach the end in view by replacing the sodium flame *F* by a hydrogen Geissler tube. The light would have to be analyzed prismatically and the period of intermittance suitably chosen. Michelson* has shown that the lines of the hydrogen spectrum are not well adapted for refined refractometer work. In the present case the number of fringes in question is only a very few (2 or 3), so that I do not think there will be difficulty for this reason.

5. The apparatus being differential in type, is particularly adapted for observing the Joule expansion phenomenon, its variation with the field, with temperature and dimensions of the core, etc. The results of the table are random examples among many data obtained with *continuous* currents. The first column shows the field within the helix, the second and third columns the expansions in millionths of the length of core for each helix separately, and the fourth column the corresponding results when both helices were in circuit. When results differed the mean value was taken. Since the motion of one fringe across the cross-hairs of the telescope corresponds to about $30/10^6$ cm (in view of reflection) and since the iron cores are about 30 cm long, the elongation is about 10^{-6} per fringe. Now the motion of less than one-tenth fringe is discernable; hence an elongation of one ten-millionth is easily recognized.

| Field dynes/cm ² . | Expansion $\times 10^6$. | | | Remarks. |
|----------------------------------|---------------------------|---------|-------|----------------------------------|
| | Core A. | Core B. | Both. | |
| 4 | 0 | 0.0 | 0.0 | Incipient shifting. |
| 7 | + .2 | - 0.2 | 0.0 | |
| 11 | .3 | - 0.6 | 0.2 | |
| 14 | .6 | 0.6 | 0.2 | |
| 18 | .8 | - 0.8 | --- | |
| 20 | .8 | - 1.0 | 0.3 | Continual shifting. No rotation. |
| 22 | 1.2 | - 1.5 | 0.4 | |
| 30 | 1.2 | - 1.2 | --- | |
| 44 | .7 | .5 | 0.2 | Much rotation. |
| 100 | --- | --- | 0.5 | Rotation. |
| 600 | --- | --- | --- | Rotation. |

* Michelson: *J. c.*, Annex, III.

Taken as a whole, the results of the table agree in character with Bidwell's* interesting investigations. They show that the expansion increases to a maximum, attaining it in a field between 20 and 30 dynes, at which the iron is probably saturated. After this the data are obscured. The present maximum expansions are smaller than Bidwell's and occur at an earlier stage of magnetization. Thus an elongation of 1 to 1.5 millionths was rarely exceeded.

Although my experiments were made in fields as large as 600 dynes, the results above 30 dynes are of no value. For in larger fields than this the fringes showed more and more rotation intermixed with the translation. This indicates that the suspended cores were flexed by the field, or that they contained inherent torsion which in a field gives rise to a Wiedemann effect, or both. Probably flexure supervened. To give an example among many: In a field of 330 dynes the fringes for helix *A* showed clockwise rotation, the fringes for helix *B* counter-clockwise rotation. The two cores together showed a definite translation of about one fringe, without rotation. This would correspond to compensatory flexures,† and in large fields the real phenomenon was masked by this discrepancy.

If the results are studied with reference to weak fields, the curve is found to terminate *abruptly* in the abscissa. No elongation was observable in fields less than about 7 dynes. For fields larger than this, an increment of field less than a single dyne produced an observable change of elongation. This result is sufficiently remarkable to deserve detailed study.

There is a final point to be mentioned. In a field of about 20, in which the elongation of the above rods was most pronounced, the observed effect with a single helix in circuit was such as to correspond to a shifting of the fringes whenever the circuit was closed, with no return of fringes apparent on opening. On closing, about 1.5 fringes visibly and invariably moved across the cross-hairs of the telescope; on opening, the return was either partial or (apparently) absent altogether. I was even able to make over 100 fringes move across the field by continually closing and opening the circuit. On inserting the other helix alone the result was the same but reversed in direction. With both helices in circuit there was but little motion. I was at first inclined to refer this observation to an increase of temperature due to magnetization. The passage of $\frac{1}{2}$ fringe corresponds to an elongation of 5×10^{-7} . The equivalent rise

* Bidwell: See Ewing's Magnetic induction in iron, p. 238; Phil. Trans., 1888, p. 205; Proc. Roy. Soc., xlvii, p. 469, 1890.

† Unfortunately the soft Norway iron obtainable here is not quite straight; and since all mechanical treatment hardens and injures the iron, I was obliged to content myself with the best samples in the lot at my disposal.

of temperature in iron would be 0.04°C. , which in case of several hundred repetitions would be otherwise appreciable. Hence this observation, though distinctly marked, must be an illusion and due to the fact that the magnetization takes place much more slowly than the demagnetization. It is a curious feature, however, that for fields above and below the sensitive value in question, continued shifting does not occur.

6. The results obtained are applicable to intermittent currents of low frequency at once. From the dimensions given, the self-induction L of the two helices is not above 0.5 henry, each. If the frequency be kept below 100 per second, the current would not be dephased more than about 0.2 period behind the electromotive force; and there would be no serious interference with visibility from this cause since the partial electromotive forces of each helix as well as the total electromotive force are in advance of their respective currents by the same fraction of a period. For a simple harmonic variation of electromotive force at the source, the impedance introduced at each coil for frequencies, 0, 10, 50, 100 would be about 11, 34, 158, 316, respectively. To produce appreciable expansion of the iron cores one would, therefore, merely have to increase the electromotive forces accordingly.

In the following experiments, however, the current is actually made and broken. Since the extra current is thus evoked and necessarily introduced at the *maximum* of electromotive force, its effect will be a maximum. From the given dimensions one should expect the current in successive intervals of 0.01 sec. each to be 0.20, .37, .50, .60, etc., of the maximum. It will thus be necessary, if the frequency is as high as 100, to use five times the battery power needed in case of continuous currents under the same circumstances. This is also the effective quantity of current whether one or both helices are in circuit, seeing that resistance and self-induction in the two cases increase in like ratio.

In the following table I give the results obtained for low frequencies, using a Foucault interrupter of the usual pattern. The first and third columns show the value of the fields had continuous currents been used; the second and fourth columns the corresponding appearance of the interference fringes ("clear" denoting maximum visibility).

| One helix in circuit. | | Both helices in circuit. | |
|-----------------------|---------------|--------------------------|------------------------------|
| Fields (maxima). | Fringes. | Fields (maxima). | Fringes. |
| 18 | Hazy | 16 | all clear. |
| 22 | Just vanished | 18 | clear. |
| 27 | Vanished | 21 | clear. |
| 36 | do | 26 | $\frac{3}{4}$ of face clear. |
| 57 | do | 34 | do. |
| 70 | do | 40 | do. |
| 100 | do | 49 | vanishing. |

Conformably with § 5 the fringes vanish much sooner (i. e. for smaller fields) when only one helix is in circuit than when both are inserted. Since only about 30 per cent of the full current is effective, the minimum field producing elongation and, therefore, vibration of the cores is about of the same value as before (§ 5).

It is difficult to give the vanishing point. The fringes do not disappear uniformly over the whole face, but parts of the field of view linger longer than others. This again points to rotation of fringes, parts nearer the axis vanishing last. Many other experiments of a similar kind were made, without, however, adding essentially to the above.

7. The question finally occurs whether the above arrangement is sufficient to test the speed of transmission of an electric signal or impulse from helix *A* to helix *B*. The equations for this case were originally worked out by Lord Kelvin* and since by others; but I do not know that much direct experimentation has been given to the subject, seeing that in deep sea cables the leakage obscures the law. As the underlying differential equation is of the same form as that which occurs in heat conduction, many of the electrical problems have virtually been solved in the analytic theory of heat. Thus if the potential at the initial point varies as $\sin 2\omega t$, the distribution of potential along the wire is given by

$$E^{-z\sqrt{\omega}} \sin(2\omega t - z\sqrt{\omega})$$

where $z = x\sqrt{kc}$, x being the distance of transmission from the initial point, c the electrostatic capacity per unit of length, k the electrostatic resistance per unit of length. Thus the speed of transmission of like phases is $2\sqrt{\omega/kc}$, increasing, therefore, as the square root of the frequency of vibration, while

* See Math. and Phys. papers of Sir William Thomson, p. 61 et seq., where the expression for capacity is also given.

the time of transmission ($z/2\sqrt{\omega}$) varies as z already given and proportionally to the square root of the periodic time. Finally the magnitude of oscillation decreases in geometric progression as distance increases arithmetically.

In case of a circuit made and broken as above, the quantity which may be called the retardation a (seconds) has the value

$$a = .02332 CRx^2 10^{-6}$$

where C is the capacity in microfarads per knot, R the resistance in ohms per knot, x the length of cable in knots ($185,526^{\text{cm}}$). The equation would not be changed if all data were referred to the centimeter. The current reaches 50 per cent of its value after the lapse of $6a$ seconds, and its full value (nearly) after about $20a$ seconds, no matter what cable be chosen. Finally the capacity of the cable is $C = .0486 Kx/\log D/d$, where D/d is the ratio of diameters of cable envelope and cable core, K (microfarads) the specific inductive capacity of the substance of the envelope.

To test the speed of transmission along a wire with resistance and capacity only, let the wire be wrapped bifilarly and the capacity of the bobbin increased by surrounding the insulation of the wire by a continuous conductor. I will suppose this to be done with silk-covered wire about 1^{mm} in diameter with sheets of tin foil around the successive layers to increase the capacity. Thus if $D/d = 1.1$ and $K = 2$, then $C = 2.5$ microfarads. Hence the retardation per knot, if the resistance per knot be 40 ohms, is $a = 2.3/10^6$, and the current would attain its full value in about 50 millionths of a second, for the first knot of cable. For succeeding knots the conditions are more favorable.

It follows, therefore, that if the above apparatus is to measure retardations along about 1.5 knot of the wire specified, the period of vibration of the iron cores must be of the order of 0.0001 second. In this time the change of phase would be complete and one fringe would pass the cross-hairs.

The point finally at issue is whether the above apparatus can respond to 10,000 vibrations per second. It ought not to be difficult to break the current as often as this, Gordon's* rapid speed break reaching 6000 per second. If the iron cores of the above helices be clamped in the middle with the ends free to vibrate as an elastic solid, longitudinally, a length slightly over 30^{cm} would vibrate with the given frequency. This is about the length of core used above.

On the other hand, it is necessary to wind the helices for

* Gordon: Electricity and Magnetism, p. 49.

smaller self-induction, retaining the condition of identity. Thus if only a single layer of wire is used on the above frame, and if the core of half the above diameter (made tubular or cross-shaped in section) be inserted, the self-induction will be reduced to .002 henrys, and the impedance for 10,000 vibrations to 126 ohms. The field of this helix is 14 dynes per ampere, and since half this value is just sufficient to elongate the cores appreciably, about 90 volts would be needed to produce the vibration, apart from the favorable condition of resonance. Finally, in view of the large factor $R/L = 750$, after 0.0001 second the extra current has kept the current strength reduced to about 1 per cent of the maximum value. Hence the current must be 100 times stronger than when it acts continuously, $R/L = 750$, requiring 70 volts to maintain it.

To summarize: Setting considerations of mechanism aside, an arrangement of the kind shown above supplied with about 100 volts ought to indicate the retardation along something over a single knot of wire of the high capacity stated, inserted between the helices. This retardation will be exhibited by the passage of one yellow interference fringe across the cross-hairs of the telescope.

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ART. X.—*The Multiple Spectra of Gases*; by JOHN TROWBRIDGE and THEODORE WM. RICHARDS.

IN a recent paper upon the spectra of argon we have shown that the two different spectra of this gas are dependent primarily upon the electrical conditions which cause the gas to glow. The continuous discharge of a high tension accumulator through the gas produces the red spectrum, while the discharge of a condenser, provided that its oscillations are not damped by the resistance of the tube, or other resistance or impedance, produces the blue spectrum.

It becomes now a matter of great interest to determine if the same conclusions apply to other gases, a subject which has already been studied in detail by Wüllner and others. The chief difference between our work and the earlier investigations are: first, the use of a high tension accumulator instead of an electrical machine or Ruhmkorff coil as the source of electricity; and secondly, the introduction of varying ohmic resistance or impedance between the plates of the condenser in order to study the damping of the spark. It is the object of this paper to emphasize anew the importance of the electrical conditions of the circuit, and to call attention once more to the fact that the behavior of most elementary gases is in every respect similar to that of argon.

With regard to the spectrum of nitrogen, it has been known for a long time that two spectra could be obtained by means of appropriate changes in the density of the gas, as well as by the introduction of the condenser; but not all investigators have put the same interpretation upon their results. So varying are the views, that Ångström* and Thalen† believed the familiar channelled spectrum to be due to impurities in the gas. Plücker and Hittorf,‡ Wüllner§ and Salet|| have proved this view to be false, but they had not at hand the constant current of high tension at our disposal and their nitrogen was obtained from air containing argon, so that a revision of their work promised to be of great interest.

With our Planté battery of ten thousand volts we have obtained the usual two different spectra of nitrogen by varying suitably the electrical conditions of the discharge. By means of a continuous discharge with no spark gap or brush dis-

* Pogg. Annalen, cxliv, 300.

† Bull. soc. chim. (2), xxv, 183.

‡ Roy. Soc., Proc., xiii, 153. Phil. Mag. (4), xxviii, 64.

§ Pogg. Ann., cxxxv, 497, cxxxvii, 337, cxlvii, 321, cxlix, 103, cliv, 149.

|| Ann. Chem. Phys. (4), xxviii, 52. Hasselberg, Ames and others have also studied the nitrogen spectra.

charge in the circuit through nitrogen under varying pressure, we always obtained the channelled spectrum. The glow in the capillary tube, as well as the positive and negative light, was of a delicate pink color under these conditions; a color not unlike the red glow of argon. When an air-gap, over which the battery discharges in a brush, is introduced into this circuit, the glow becomes more violet in tinge, and the spectroscope shows that the red bands almost if not wholly disappear, while the blue and green ones retain their positions. Under these conditions the capillary tube is filled with a pure blue glow, less intense and vivid than that of the argon, however.

When the condenser is introduced, the whole appearance of the tube is utterly transformed. The blue color of the tube at once changes to a rich bluish green, and the channelled spectrum gives place to bright lines, already well known and mapped. This line spectrum corresponds to the blue spectrum of argon. When the oscillations of the condenser-discharge are damped by means of a suitable resistance or self-induction interposed between the condenser plates, a channelled spectrum reappears; but in this case the glow in the tube is of a bluish white color, the positive and negative lights being of a bright yellow. Whether or not this channelled spectrum is, as it seems, exactly like the one obtained by means of a continuous discharge, photographic measurement will show. This last appearance is probably the usual one obtained by means of the Ruhmkorff coil, for then the oscillations induced by the primary condenser are damped by the impedance of the secondary coil and the resistance of the tube.

The spectrum of hydrogen is usually supposed to consist of four bright lines, $H\alpha$ 6563.0 (C), $H\beta$ 4861.5 (F), $H\gamma$ 4340.7 (G^1), $H\delta$ 4101.9 (h), as well as several in the extreme violet and ultra violet.*

Other spectra have been observed also; but owing to the partial understanding of the conditions required to produce them, the voluminous literature† upon the subject leaves a confused idea in the mind of the reader. The continuous discharge of a high tension accumulator through hydrogen gas at tensions varying from 0.05^{mm} to 3^{mm} and more yields a beautiful white glow in the capillary of a Geissler tube, while the strata in the positive and negative light are often alternately pale pink and pale blue. When examined by a spectroscope with a broad slit, the light from this discharge appears

* Ames, Phil. Mag. (5), xxx, p. 48 (1890).

† Ångström, Vogel, Lockyer, Fievez, Wiedemann, Huggins, Wüllner, Hasselberg, Balmer, Grünwald, Villari, Schuster, Salet, Smyth and others. For references see O. Dammer; Anorgan. Chem. i, 369.

to consist of bands similar to that of nitrogen, as well as of bright lines; but when the slit is narrowed every band is resolved into a multitude of sharp lines of varying intensities,* among which the four usual hydrogen lines, although present, are by no means especially prominent. A large capacity is required to change this spectrum into the familiar four-line spectrum which is comparable with the blue spectrum of argon. The change is marked by a sharp alteration in the color of the glow from white to a deep red. In the process, the bluish green line ($H\beta$) as well as the two in the violet, which retain their early position unaltered, become nebulous at their edges;† while the red line $H\alpha$ remains sharp and clear. The most marked change in the spectrum, however, is the complete obliteration of all the host of other lines covering the whole spectrum, and the obvious contrast between the oscillatory and non-oscillatory spectrum of this gas is quite as striking as in the case of nitrogen, although somewhat different in nature. This four-line deep red glow appears satisfactorily in a tension of gas of about a millimeter,—when the tension of the gas is much higher or lower the resistance is increased, the oscillations are damped, and other lines begin to appear. Curiously enough, however, the damping of the oscillatory discharge does not at first replace all the lines which were extinguished by the introduction of the condenser. At first only a sharp line in the yellow and one in the green begin to appear, and gradually others are added as the impedance is increased.

The relation of these conclusions to the varying spectra of hydrogen observed in stars leads to interesting speculations regarding the nature of the electrical and thermal conditions in the photospheres of these bodies.‡

Each of the halogens gives two spectra, one with and one without the condenser. With iodine, if any of the solid itself is present in the tube, the vapor tension is so soon altered by the heat of the discharge that the oscillatory discharge is damped and the non oscillatory substituted. Hence the former can be obtained only for a few moments.

A tube of helium made by Professor Ramsay, the kind gift of the Hon. R. J. Strutt, gave a brilliant yellow glow under the influence of the continuous discharge, and a brilliant blue with the condenser discharge, but since the bright helium lines remained in each, and every other important line in the blue spectrum proved to be an argon line, it is evident that the oscillations produced no considerable effect upon the helium.

* Smyth, Wied. Ann. Beiblätter (2), vii, p. 286. Wüllner observed this spectrum but did not measure the lines.

† E. Villari, Fievez, and Salet.

‡ E. Ebert, Wied. Ann., liii, 1894.

As Crookes and others have already pointed out, since many gases yield different spectra under the influence of varying electrical conditions, it is evident that the fact of the existence of two well-marked spectra of argon gives not the slightest presumption in favor of the hypothesis that the new gas is a mixture. In order to discover if argon possesses a dual nature, the gas must be split up in such a way that its components give different spectra under like electrical conditions; then alone would the evidence of the spectroscope be of weight in proving the dissimilarity of the several parts.

The results of this work are thus far only those which were to have been expected from a high tension galvanic battery, reasoning from the work of other investigators with the Toeppler-Holtz machine. The battery, however, gives a current so admirably constant and so easily regulated as to its tension, that we hope to be able to use it as a means of determining whether the oscillatory discharge produces its effect simply by increasing the temperature, or because of some inherent property in the manner of the discharge.

It is our intention to extend the investigation by the systematic photographic study of the action of the varying discharge upon all the elementary gases in the purest condition, as well as upon mixtures under widely varying conditions of temperature and pressure.

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ART. XI. — *Studies in the Cyperaceæ*; by THEO. HOLM.

III. *Carex Fraseri* Andrews, a morphological and anatomical study. (With Plate IV.)

THIS very rare and local plant has a peculiar and striking appearance which at once distinguishes it from most of the other species of *Carex*, and since we have, also, observed several peculiarities in its internal structure, we have thought it worth while to treat this species for itself.

As regards the morphological characteristics of our plant, we have already in a previous paper* called attention to its monopodial ramification. The foliar organs are very singularly developed and represented by four or five scale-like, membranous leaves and one very broad and deep green leaf, being the only assimilating one of the shoot.

The scale-like leaves have long and perfectly closed sheaths, while the single, proper leaf is not sheathing, the base being merely convolute. This leaf is, then, destitute of any sheath and has no ligule, and the one margin or sometimes both are minutely folded, giving the leaf the appearance of being finely serrate along the margin. These characters, the lack of sheath and of ligule, distinguish this species from most, if not all the other representatives of the genus *Carex*. It is true, however, that in some of our very broad-leaved species, e. g., *C. plantaginea*, *C. platyphylla*, etc., the leaf-sheath is very short and breaks open at an early stage, but it is, nevertheless, easily distinguishable while the leaf is still in bud, and the ligule is well developed and persists for a long time. Species with the leaf-margin undulate, as in *Carex Fraseri*, are not known in this genus except that a form of *C. pallescens* L. is occasionally met with, of which the bracts are more or less undulate, hence the distinction of the variety "*undulata* Kze." The question is, now, to decide the proper situation of these two forms of leaves, whether the large, green leaf belongs to the same axis as the scale-like ones. It appears, however, as if the floral bud is lateral, and that it is directly developed from the axil of the large, green leaf, this being the only leaf of the central, vegetative bud. The central bud is, therefore, of a short duration, of about one year only. By examining specimens of this species in the winter-time, the floral buds are observed to be situated exactly as in the other species with monopodial ramification, with the exception that each vegetative shoot has, in *C. Fraseri* constantly, not more than one single, assimilating leaf developed.

* See this Journal, vol. i, May, 1896, p. 349.

By considering the stem above ground, this is not terete or triangular as we are used to find it in the *Cyperaceæ*, but flattened, almost, in its entire length. The inflorescence bears a large number of staminate flowers at the apex, and a number of pistillate ones at the base of the staminate, all of which are supported by broad, hyaline and silvery shining bracts, almost entirely destitute of chlorophyll. The utriculus is large, membranous and much inflated. It encloses the pistil, which (Plate IV, fig. 2) is distinctly stipitate (Stp.) and with the rhacheola (Rh.) extended beyond the pistil. The development of this rhacheola is to be seen in our figure 1, where a very young pistillate flower of *Carex Fraseri* has been illustrated. It has been drawn from a flower at a very young stage, while the entire inflorescence was still inclosed in the bud for the winter. This figure shows the utriculus (Utr.) forming a low wreath and surrounding the three carpels (Carp.); on the front-side of the utriculus is a small, roundish body to be seen (Rh.), which represents the free apex of the rhacheola, being here extended beyond the flower. This fact, the extension of the rhacheola, has, already, been observed in this species by Baillon (l. c.); besides it is far from uncommon in other species of *Carex*, as recorded by the writer in a previous article upon this subject.* In *Carex Fraseri* this processus is most frequently without any rudiments of flowers, but sometimes a few imperfect have been observed.

Another peculiarity of the pistillate flower in this species is the occasional development of four stigmata; besides that Boott (l. c.) has described and figured a flower with two utriculi, thus originating from two separate prophylla, a fact which seems to be exceedingly rare in the *Cyperaceæ*.

But by considering these morphological characteristics of *C. Fraseri* as a whole, there does not seem to be any character important enough for distinguishing it generically from the other *Carices*, inasmuch as the peculiarities of the pistillate flower, the extended rhacheola for instance, is not sufficient for admitting any such distinction. Its most peculiar morphological character is, no doubt, the absence of a closed sheath and ligule in the assimilating leaf.

We will, thereupon, examine the anatomical structure of our plant.

The leaves, the scale-like ones, are membranous and almost destitute of chlorophyll. The epidermis forms, on both faces of the leaf a homogeneous tissue of rectangular cells with the walls slightly undulate. Stomata are either entirely absent or merely present in a very small number on the dorsal face. A

* This Journal, vol. ii, September, 1896, p. 216.

transverse section of one of these scale-like leaves shows us a structure, which in most respects reminds us of a leaf-sheath, viz: the development of large lacunes between the mestome-bundles, the non-differentiation of the mesophyll and the partial absence of vessels in the mestome-bundles, while the leptome-elements are well-developed. The stereome is, also, characteristic, forming large groups on the dorsal face of the leaf underneath the leptome-side of the mestome-bundles; besides it, also, forms isolated groups between the bundles. The corresponding groups of stereome on the ventral face are smaller, and the cell-walls are relatively thin, leaving a large lumen. The free part of the scale-like leaf shows a similar structure, and the free margins consist only of two strata of cells, corresponding to the dorsal and ventral epidermis.

The large, green leaf has a similarly developed epidermis on both faces, but stomata are present in large number on both faces, but most numerous on the inferior, the dorsal face. These stomata show the same, characteristic form as recorded by Schwendener (l. c.), but they are constantly in niveau with the surrounding epidermis-cells. Very characteristic of the epidermis is the total absence of epidermal expansions such as hairs or thorns, which are so common in most of the other *Cyperaceæ*.

There is, however, one kind of epidermal expansions which our plant has in common with the other *Cyperaceæ*, viz: the peculiar silicious cones, which are noted to project from the bottom of the epidermis-cells and often reaching the superior wall. These cones may occur from one to two in each cell (Plate IV, fig. 3), but they are only present in those strata of epidermis which cover the groups of stereome on the dorsal face of the leaf-blade.

We have stated above that the epidermis forms an almost homogeneous tissue on both faces of the blade, excepting a few strata of somewhat narrower cells, covering the mestome-bundles, but this divergency in shape is too small to be of any importance. We should, however, expect to observe quite a considerable variation in some of the epidermal strata, at least on the ventral face of the blade. We know from the numerous and most important writings of Duval-Jouve upon the structure of the *Cyperaceæ* and the *Gramineæ*, that certain strata of the epidermis have usually attained a special development, widely different from the other epidermis-cells, and of which the function is to facilitate the folding or closing of the leaf-blade so as to prevent the surface from being exposed to the strong sunlight, thus protecting the leaf against a too rapid evaporation. These cells were by Duval-Jouve named "bulliform-cells" (Duval-Jouve: *Histotaxie* l. c.) and they differ

very much from the surrounding cells in regard to their size and shape. They are often developed as vesicles with a rather thick and strongly cuticularized outer-wall, and show a great tendency to collapse, when exposed to excessive drought, while they rapidly swell up again, when brought in contact with moisture. These peculiar cells are, as a rule, located on the superior face of the leaf-blade and they are most often to be observed above the midrib, but also between some of the larger mestome-bundles in several genera, especially in the broad-leaved species.

It is easily understood, that being located where they are, these cells by collapsing naturally force the blade to become folded either as simply "conduplicate" or as "convolute." In the genus *Carex*, of the species which have been examined, this form of cells has never been observed to be missing. We have figured the most common shape and size, which these bulliform cells attain in *Carex*, e. g. figure 5, which is from *C. virescens* Muhl., a species with leaves of ordinary width, and which grows in localities not exposed to excessive drought or moisture. In some species, which inhabit places exposed to heavy winds, and which are especially characteristic of the sand-dune vegetation, the bulliform-cells are especially developed and are even supported by several strata of similar, but smaller cells, all constituting a typic closing-apparatus for the leaf-blade. Figure 6 shows such layers of bulliform cells from the leaf of *C. trinervis* Degl., a common sand-sedge from the west coast of Europe. The very narrow-leaved *Carices* have, on the other hand, not the bulliform cells so well differentiated, as for instance in *C. exilis* Dew. (fig. 4), besides similar marsh-sedges, as *C. dioca* L., *C. gynocrates* Wormskj., etc.

But our *C. Fraseri* is entirely destitute of any such bulliform cells on either side of the blade, which is the more surprising when we consider the extraordinary width of the leaves; the plant seems, therefore, to be very poorly adapted for existing outside of the damp and shaded ravines where it usually occurs.

In considering now the structure of the other tissues which compose the leaf, our plant does not differ in any essential respect from the other species of *Carex*. The mesophyll forms a homogeneous tissue all through the blade, and it consists of polygonal cells, which are closely packed on both faces of the leaf, while the central part of the leaf-blade is traversed by broad lacunes, which are only separated from each other by the mestome-bundles and the adjoining mesophyll.

Very distinct from the mesophyll is the thin-walled parenchyma-sheath, which partly surrounds the mestome-bundle, at least on the sides, extending from the stereome of the superior

face of the blade to that of the inferior. This parenchyma-sheath is not green in our plant, but colorless.

The mestome-bundles are, furthermore, surrounded by a rather thick-walled mestome-sheath (M. S. in fig. 7) which forms an uninterrupted ring all around the leptome and hadrome. The group of leptome is very well differentiated and the hadrome contains a larger number of vessels, especially ring-vessels, than is usually observed in *Carex*. On both faces of the mestome-bundles are groups of stereome (St. in fig. 7) which show the same structure as generally known in this genus. This tissue, the stereome, forms also an isolated group in the leaf-margin itself.

One feature seems, however, somewhat striking, when we consider a number of transverse sections from the entire width of the blade, viz: the uniformity in size and development of the mestome-bundles, at the same time as we observe the equality in thickness of the mesophyll between the mestome-bundles. There is, generally, in the broad-leaved species of *Carex* a distinct difference to be found in regard to the size of the mestome-bundles, besides that the mesophyll often becomes constricted in certain places so as to leave room for groups of bulliform-cells, which as stated above are absent in our plant. The sections of the leaf, as described above, were all taken from the middle of the blade, and we will now examine the very base of the same leaf, which in the other *Carices* forms a closed sheath, but which is free and merely convolute in our plant. Such sections, taken from the base of the leaf, show a structure much like that we have described for the broad part of the blade. We merely note that the groups of stereome are longer and much more narrow, besides that their cells have a considerably larger lumen. The mestome-bundles themselves show a somewhat weaker development, and the lacunes are much reduced in size from what we have observed higher up in the leaf.

The structure of the utriculus may be described in this place. Its thin, bladderlike texture (fig. 8) is due to the extraordinary thin cell-walls of not only the epidermis, but also of the mesophyll underneath this. A few mestome-bundles are observable, all of which are very weakly developed, especially in regard to the hadrome-part, and the cells of the supporting stereome are relatively very thin-walled. Utriculus, so far, corresponds to Wilczek's second type (l. c.), characterized by its thin structure and the non-differentiation of the mesophyll.

The pericarp shows a similar thin texture and is composed of three tissues, viz: a very thin-walled epidermis, a stratum of three rows of relatively thick-walled sclereids, and finally a layer of horizontally stretched cells, which form the inner

coating of the pericarp (fig. 9). The stem above-ground, which at its apex bears the inflorescence, is in our plant flattened almost in its entire length, except at the base, where it is strictly cylindric. The anatomical structure is, however, the same whether we examine the cylindric or the flattened part, except in regard to the pith, which is broken in the upper part of the stem, rendering this hollow; this character, the hollow stem, is rather uncommon in the *Carices*, although it has been observed in certain species. The epidermis of the stem is very uniform and thin-walled; it possesses the interior silicious cones, but is like the epidermis of the leaf, entirely destitute of exterior expansions. The bark-parenchyma is quite large and consists of very thin-walled roundish cells, which gradually pass over into a large tissue of polygonal cells, which occupy the greater inner-part of the stem and which represents a typical pith!

Mestome-bundles are quite numerous and form two concentric rows, viz: an outer row of large bundles, supported by heavy layers of stereome, especially on the outer side and bordering immediately on the epidermis, while the inner row of mestome-bundles is only supported by a very small layer of stereome. The bundles of the inner row are smaller and are imbedded in the bark in alternation with the mestome-bundles of the outer row. Concerning the structure of these bundles, the larger ones are exactly built up as those of the leaf, except, of course, that no mestome-sheath is developed, this being always confined to the leaf-bundles.

The rhizome of our plant is very short on account of its cespitose growth, and the ascending shoots do not push out in any considerable distance from the main rhizome. The interior structure corresponds in most respects with that of the stem above ground, viz: the development of the bark, the arrangement of the mestome-bundles in two concentric, alternating rows, and finally by the central pith. We notice, however, some characters in the rhizome by which this differs from the stem above ground, viz: the presence of an endodermis, surrounding the bundles, thus separating them from the proper bark-parenchyma. The bark itself is in the rhizome composed of rather thick-walled cells, all of which contain deposits of starch; the endodermis consists of roundish cells, which are thickened all around. As regards the mestome-bundles these are more or less surrounded by stereome, the cells of which are not very thick-walled. We notice here, as in the stem, that the two rows of bundles show a different development in regard to their relative size, besides that the larger are here perihadromatic, i. e. the leptome is central and surrounded by the elements of the hadrome. The central part of the rhizome is occupied by a thick-walled pith, the cells of which contain

starch. Considered as a whole, the structure of the rhizome of our plant agrees in most respects with that of a number of other species, which by Laux (l. c.) has been classified as representing his eighth type.

The roots of *Carex Fraseri* are numerous and cover the short rhizome with a dense mass of long and strong fibers. The interior structure of the root in the *Cyperaceæ* has long since been most ably discussed by Treub (l. c.) and Klinge (l. c.), whose comparative studies have given us the principal features by which the *Cyperaceæ* may be distinguished from the *Gramineæ* and other families of the *Monocotyledoneæ*. We have learned, for instance, that the inner bark cells in the roots of the Grasses collapse radially, while tangentially in the *Cyperaceæ*. Another and very distinct character is that in the *Cariceæ* the protohadrome borders immediately on the endodermis, thus interrupting the pericambium. The root of our plant shows now the following structure: an epidermis of usual form; a bark-parenchyma of about ten layers of roundish, thick-walled cells, some of which collapse tangentially and form thereby lacunes of very considerable width. The innermost layer of the bark is differentiated as an endodermis, the cells of which are thickened so as to represent a typical U-endodermis. We observe, thereupon, the pericambium, which in our species forms a completely closed ring, without being interrupted by the protohadrome. This fact seems to form a very singular character of our plant, thus differing from all the other *Cariceæ* which have hitherto been examined.

The central-cylinder is occupied by six relatively large groups of hadrome in alternation with groups of leptome, besides the distinct but small elements of the protohadrome, situated close to the pericambium. The greater part of the central cylinder is, however, occupied by a mass of conjunctive tissue,* which surrounds the vessels and forms in the center of the root a very compact tissue of rather large and thick-walled cells, the cell-walls being strongly lignified.

If we will now consider these morphological and anatomical characters, which we have observed in *Carex Fraseri*, it may not be denied that this species is one of the most remarkable in the whole genus, at least of those which, so far, have been examined by the various authors.

The monopodial ramification of its rhizome with its single assimilating leaf destitute of sheath, ligule, epidermal expansions and bulliform-cells in connection with its flat and hollow stem, besides the uninterrupted pericambium of the root, constitute a structure that seems almost unique in the family of the *Cyperaceæ*.

* Russow's "Geleitzellen" (l. c.), Klinge's "Leitzellen" (l. c.) and Van Tieghem's "Cellules conjunctives" (l. c.).

Some of these characters, considered by themselves, may even prove sufficient for the distinguishing of this singular species.

Washington, D. C., December, 1896.

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EXPLANATION OF PLATE IV.

- FIGURE 1.—A young female flower of *Carex Fraseri*. Carp: the carpels; Rh: the rhacheola; Utr: the utriculus.
- FIGURE 2.—Mature caryopsis of *C. Fraseri*. Rh: the rhacheola; Car: the caryopsis; Stp: the stipe.
- FIGURE 3.—Cells of the epidermis of the leaf of *C. Fraseri*, showing two internal, silicious cones. St: stereome.
- FIGURE 4.—Bulliform-cells of the leaf of *Carex exilis*.
- FIGURE 5.—Bulliform-cells of the leaf of *C. virescens*.
- FIGURE 6.—Bulliform-cells of the leaf of *C. trinervis*.
- FIGURE 7.—Mestome-bundle of the green leaf of *C. Fraseri*. Ep: epidermis; St: stereome; M. S: mestome-sheath; transverse section
- FIGURE 8.—Transverse section of the utriculus of *C. Fraseri*. Ep: epidermis.
- FIGURE 9.—Transverse section of the pericarp of *C. Fraseri*. Ep: the exterior, proper epidermis.

ART. XII.—*A Simple Instrument for inclining a Preparation in the Microscope*; by T. A. JAGGAR, JR.

THE instrument* here described was devised for use in petrography, especially in connection with the Michel-Lévy† and von Fedorow‡ optical methods of determining feldspars. The device may be of service to microscopists in other fields as well, where it is frequently necessary to examine in reflected light the surface of objects, whose relief above the object-glass makes tipping imperative if one desires to view the preparation on all sides.

In the study of thin sections of rock in the polarizing microscope, the constituent minerals are sliced on planes bearing usually no definite relation to the optical symmetry of the individual crystals; in order to obtain sections parallel or perpendicular to directions of optical constancy in particular minerals of such a rock section, it has been necessary, in the past, to seek out individuals whose orientation chanced to give the results desired, or to average a number of approximately accurate sections, or to isolate the mineral and grind special sections oriented with reference to known cleavages or crystal faces. By using the so-called "Universal Stage," which permits rotation of the object-glass about two axes at right angles to each other, von Fedorow has shown that a crystal section may be oriented at will with reference to the polarization plane of the nicols, by simply inclining it, first in one direction, then in a second at right angles to the first, until at length the desired optical effect is observed.

For certain measurements of extreme precision in microscopical crystallography, the graduated circles of the universal stage are indispensable: but for the determination of the feldspars by symmetrical extinctions, or for conoscopic work, in petrography, all that is required in practice is the means of tipping the slide with delicacy in any azimuth at will. An instrument for this purpose should be simple, inexpensive, easily manipulated, adaptable to any microscope and instantly removable; to meet these requirements the instrument here described has been constructed.

The accompanying figure (fig. 1) shows the construction of the instrument in vertical section and plan, natural scale. It is

* The author's model was made by C. Milton Chase, mechanician, 45 Cambridge st., Boston, Mass. The Bausch and Lomb Optical Co., of Rochester, N. Y., have completed a new model, adaptable to the stage of any microscope, when size and distance apart of clip-holes are specified.

† A Michel-Lévy: *Étude sur la détermination des feldspaths dans les plaques minces*, au point de vue de la classification des roches. Paris, 1894.

‡ E. von Fedorow: *Universal-(Theodolith-) Method in der Mineralogie und Petrographie*. II. Theil: *Krystall-optische Untersuchungen*, *Zeitschrift für Krystallographie*, etc., xxii, 229-268, 1893.

simply a clip (*c*) for the object-glass, supported 15^{mm} above the surface of the stage by a ball-and-socket joint (*b*); a long key (*k*), fitting a triangular aperture (*h*) in the clip-arm (*a*) from

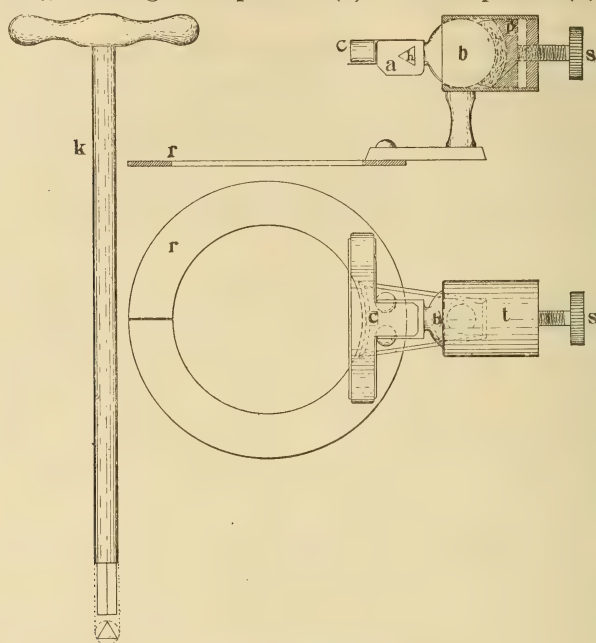


Figure 1 (natural scale).

either side, secures delicacy of manipulation and enables the operator to incline his preparation in any direction by a simple movement of the fingers. A thumb-screw (*s*) in the end of the barrel (*t*) that serves for ball socket, permits adjustment of the tension on the ball by pressure on a brass plate (*p*) faced with cork, which fits the surface of the ball.* In the model figured, the foot-ring (*r*) fits the center of the Fuess mechanical stage, and the rectangular movements of the latter allow ample horizontal adjustment, for bringing different portions of the section into the visual field. The foot of the new model (fig. 2, see foot note p. 129) is made adjustable to the clip-holes of any stage, and the elevated clip attached to the ball-and-socket is of such form that free horizontal movement of the object-glass by hand is possible in all directions; furthermore, the foot-plate is so shaped that in special cases it may be simply slipped under the ordinary clips, and thus held in any desired position.

* This arrangement was suggested to the writer by Professor Goldschmidt's two-circle contact goniometer, where the crystal is centered by a ball-joint and key: *v. this Journal*, Oct., 1896, p. 285. On Crystal Measurement by means of Angular Coördinates, and on the use of the Goniometer with two Circles; by Charles Palache.

The chief uses of this instrument in petrography are the rapid determination of maximal and minimal extinction and absorption values, the orientation of feldspar twins for deter-

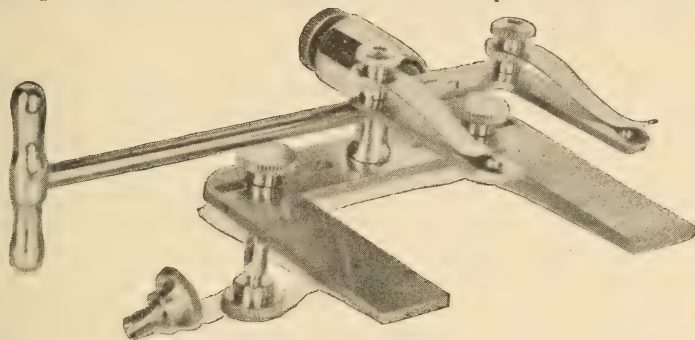


Fig. 2. New model of instrument, showing revised form of foot-plate, with sliding posts adjustable to clip-holes of any stage; an extra pair of these posts shown at the left. Key is in position. The clips may be inserted in all four corners of the elevated clip-plate, and thus turned backward or cross-wise.

mination by Michel-Lévy's method, and the inclination of the section to give well-defined interference figures in convergent light. This latter use has been tested by the writer with a section of calcite cut parallel to the face of the cleavage rhombohedron R (10 $\bar{1}$ 1). The interference figure given by this section, when placed horizontally in the microscope in convergent polarized light, is a black bar, representing one arm of the basal cross, and a small arc of two of three faintly defined chromatic rings on the extreme border of the field. If we now incline the section in the ball-and-socket clip, the *complete cross and rings* may be brought into the field and accurately centred, thus bringing the *c* axis into coincidence with the axis of the microscope. This implies rotation of the section through an angle of over 44°, which is about the working limit of the instrument, and is of course far greater than would usually be required.

For this work, where very high powers are used, a tube must be provided for raising the conoscopic condenser 15^{mm} to the level of the elevated object-glass. In addition it is desirable that this condenser be mounted in a steeply conical cell, in case any considerable tipping of the section about its apex is required; the high-power objectives offer no obstruction in this respect, as they are usually mounted in cells sufficiently tapering. For interference figures from mineral sections where such high magnification is unnecessary, a special long-focus conoscopic combination of objective and condenser is recommended, as these allow ample space for free inclination of the object-glass.*

* R. Fuess in Berlin makes such a combination for use with the Fedorow Universal Stage: v. Ergänzungen zu den Preis-Verzeichnissen 1891 und 1894, R. Fuess, 1895, p. 18, No. 14, last paragraph.

ART. XIII.—*Nocturnal protective coloration in Mammals, Birds, Fishes, Insects, etc., as developed by Natural Selection*;* by A. E. VERRILL.

MUCH has been written in respect to the imitative and protective colors of these groups, as seen by daylight, and the bearing of these facts on natural selection is well known. Very little attention has been paid to their colors, as seen by twilight, moonlight, and starlight. Yet it is evident that protection is more needed during the night than in the daytime, by a very large number of species. This is the case with those that move about in search of their food at night, as is the habit of numerous forms of small mammals, such as rodents (rats, mice, arvicolæ, etc.), insectivores (moles, shrews, etc.), many herbivores, various marsupials, and members of other orders. Many carnivorous species, which seek their prey at night, will also find advantages in such protective colors, for thus they will more easily escape the notice of their prey. Hence many nocturnal carnivores are black or nearly so, as the mink, fishes, some bears, etc. The same principles will apply to birds, reptiles, fishes, and to insects, both in their larval and adult states, for many members of all these groups are very active at night and hide away in holes or beneath dense herbage by day. Moreover, large numbers of birds, fishes and insects, that are active by day, rest in exposed situations at night, and are thus liable to be destroyed by nocturnal enemies. Most small birds roost in trees, bushes, or reeds, and therefore need protection while sleeping. Most small fishes, that are quiet at night, rest among sea-weeds, grasses, and stones, or else directly upon the bottom, exposed to the attacks of many nocturnal carnivorous species. The struggle for existence is severe among such species. It is to be expected, therefore, that instances of nocturnal protective coloration will become numerous when looked for. The chief object of the present paper is to call the attention of more observers to this subject.

In many cases the same colors are equally protective in daylight and at night. This is the case with the green colors, so often seen in the plumage of birds that live among foliage, and with the various shades of brown and gray,—common colors of birds, and mammals that live on the ground, among rocks or dead leaves, and of those that live on or among tree trunks. The same applies to the white colors of mammals and birds in winter and in the arctic regions. But there are

* Abstract of a paper read before the Morphological Society, Dec. 30, 1896.

many colors that are not in the least protective by day, yet are eminently so by night. In general, the black and very dark colors, common in mammals, birds, and insects, are protective at night and not by day. One of the most obvious effects of moonlight is to give very strong or black shadows, in which black or dark animals become invisible, or nearly so. This invisibility is often increased by sharply contrasted stripes or patches of white or light yellow, which look like patches of moonlight falling across a dark shadow, and thus serve to break up the outlines of bird or beast that might otherwise be recognized. Transverse black or dark brown bands on fishes that rest among eel grass or sea weeds, tend to render the outlines of the fish indistinct, because they look like the shadows and shaded surfaces of the weeds. Black fins and tails have a similar effect, in concealing or destroying the outline of fishes. The striped colors of the tiger have the same effect when it lives among the stalks of reeds, etc., and is probably much more effective in twilight or moonlight than by day. The same is true of the spotted pattern of the leopard, panther, and jaguar.

A great number of small nocturnal mammals, belonging to diverse groups, have dark gray and grayish-brown colors (mouse-colors) which are highly protective at night, but are usually not at all so in the daytime, for such colors are conspicuous among the green herbage which they frequent, and on which most of them feed. Moreover, nearly all such mammals hide away in holes in the daytime. I have noticed that our common meadow mouse (*Arvicola*) which is very dark gray, is scarcely to be seen even in a moonlight night, in localities where it is very abundant among grass, and when large numbers are so near that the sound made by their teeth in feeding is very evident. Among insects there are multitudes of instances of colors that are evidently nocturnally protective and which can be explained only on the basis of natural selection, favoring the variations in color that are in this way most useful. Such colors may or may not be more or less protective in the daytime. Frequently they appear to be just the opposite of protective in the daytime. Thus many butterflies have bright colors that are very conspicuous by daylight and which do not in any way match their customary surroundings. This applies to those species that are black or dark blue, striped or blotched with white, yellow, or orange, and to many species that are spotted or striped with red, orange, and black on the upper surface of the wings, and often also beneath, so that they are conspicuous whether flying or at rest. Their active habits and acute senses probably give them fair protection by day. At night, when resting with the wings folded, the colors

of the under side of the wings usually blend very perfectly with that of the flowers on which they roost. Many of our species of *Argynnis* and allied genera are marked with red, orange, and brown, while there are bright silvery patches on the under side of the wings, which are exposed when at rest. I have observed that these butterflies become very inconspicuous in the moonlight, when sleeping on the goldenrod and other favorite flowers, and that their silvery spots imitate very closely the dew-drops that surround them.

Numerous nocturnal insects that live on the ground are black or dark brown, which are colors that are protective only at night. This is true of most ground beetles, many crickets, cockroaches, ants, etc. Many of these insects hide away in the daytime, so that no protective colors are then needed. But many insects that are exposed both during the day and at night have acquired green or yellowish colors that are protective at all times, when living among foliage. Green grasshoppers, katydids, etc., are examples.

In general, patches, stripes, or spots of strongly contrasted dark and light colors are more likely to be of use by moonlight than by daylight, whether on birds or insects. Reptiles are to a large extent diurnal in their habits and many kinds hide in holes and crevices when at rest, so that our native species of this group appears to afford few good instances of evident nocturnal protective colors, though many may occur when the habits of tropical species become better known. Among nocturnal amphibians protective colors are common, and in many cases they appear to be exclusively for nocturnal protection. Our native nearly black species of salamanders (*Amblystoma punctatum* and *A. opacum*) have conspicuous spots or blotches of white or light yellow. It is evident that these colors have been acquired by natural selection in consequence of the nocturnal protection that they afford.

ART. XIV.—*Nocturnal and diurnal changes in the colors of certain fishes and of the squid (Loligo), with notes on their sleeping habits* ;* by A. E. VERRILL.

WHILE investigating the nocturnal habits and colors of some of our native marine fishes, in 1885 to 1887, at Wood's Holl, Mass., in the laboratory of the U. S. Fish Commission, of which I had charge at that time, I made the unexpected discovery that a number of species had the peculiar habit of assuming, while sleeping, a style of coloration quite unlike that seen in the daytime. Numerous other duties prevented me from making as many observations of this kind as I wished, at that time, nor have I since had opportunities to continue them. Therefore I have decided to publish these incomplete observations, with the hope of inducing other naturalists to continue such studies in some of the various zoological stations that are now established.

Most of my observations were made late at night, between midnight and 2 o'clock A. M., when everybody else had retired. The gas jets near the aquaria were turned down so low as to give barely light enough to distinguish the forms and colors of the fishes. Under these conditions, by using great care not to cause any jar of the floor, nor sudden movements of any kind, I succeeded in observing many species asleep. Most fishes sleep very lightly and are aroused by almost imperceptible vibrations of the air or water. Some of these fishes took unexpected attitudes while asleep.

In many cases the change of color from that seen while awake, or in the daytime, consisted in a simple increase in the depth or intensity of the colors, the pattern of colors remaining the same. This was the case with several species of flounders. Those that are spotted or mottled with dark pigment showed their markings much more strongly, or in greater contrast with the ground-color, than by day. Several species of minnows (*Fundulus*) which are marked either with longitudinal or transverse dark bands, have these markings more decidedly black and better defined than by day. The same is true of the king-fish (*Menticirrhus nebulosus*), in which there are obliquely transverse dark stripes that come out more strongly at night than by day.

The black sea-bass (*Serranus furvus*) and the sea-robins (*Prionotus palmipes* and *P. evolans*) presented the same phenomena. Several species of trout (*Salvelinus fontinalis*, etc.) were observed to become much darker at night than in the daytime, but I was not sure that any of those observed were asleep at the time.

* Abstract of a paper read before the American Morphological Society, Dec. 30, 1896. These observations were also communicated to the Connecticut Academy of Sciences, in 1888, but were not published.

It is well known that trout, flounders, and some other fishes are able to change their colors, even in the daytime, according to the color of their surroundings. Therefore a darkening of the colors at night is to be expected, even if not asleep. But in all the cases mentioned above the nocturnal change of color is of a protective character, as explained in the preceding article.

Other fishes, however, show much more remarkable changes. Among these the scup or porgy (*Stenotomus chrysops*) is one of the best examples. This fish, when active in the daytime, usually has a bright silvery color with iridescent tints. But at night, when asleep, it has a dull bronzy ground-color and the body is crossed by about six transverse black bands. When one of these fishes, with this coloration, was awakened by suddenly turning up the gas, it immediately assumed the bright silvery colors belonging to its daytime dress. This experiment was repeated many times, on different individuals, with the same result. As this fish naturally rests among eel-grass and seaweeds, the protective character of its nocturnal colors is obvious.

A common file-fish (*Monacanthus*, sp.) was observed that presents a very decided change in color pattern. This species, in the daytime, is mottled with brown and dark olive-green, and the fins and tail are a little darker than the body, but when asleep, at night, its body becomes pallid gray or nearly white, while the fins and tail become decidedly black. These colors are decidedly protective at night, or in a feeble light, among rocks and weeds, where it lives. This and other species of file-fishes, when sleeping, would usually rest on the bottom with the back leaning against the glass of the aquarium or against a stone at a considerable angle.

The common tautog or black fish (*Tautoga onitis*) has the curious habit of resting upon one side, half buried among gravel, or partly under stones, and is often curved in strange positions. It is easy to imagine that the flounders originated from some symmetrical ancestral form that acquired, like the tautog, the habit of resting upon one side, at first only when sleeping, but afterwards continually, owing to the greater protection that this habit and its imitative coloration afforded. The one-sided coloration and the changes in the position of the eyes, etc., would gradually follow in accordance with well known laws of evolution.

The common squid (*Loligo Pealei*) was observed sleeping on several occasions. At such times it rests in an inclined position, on the tip of its tail and on the basal parts of the arms, which are bunched together and extended forward, so that the head and anterior part of the body are raised from the bottom, so as to give room for breathing. The siphon tube is then turned to one side. Under these circumstances the color is darker and the spots more distinct than when it is active, owing to the expansion of the brown and purple chromatophores.

ART. X V. — *The STYLINODONTIA, a Suborder of Eocene Edentates*; by O. C. MARSH.

IN the autumn of 1873, the writer obtained in the Eocene deposits of Wyoming the remains of an extinct mammal of great interest. The most striking feature was the lower molar teeth, all essentially alike, and inserted in deep sockets. They were nearly cylindrical in form, and all grew from persistent pulps. The outer and inner faces were covered with a thin layer of enamel. This type specimen was described by the writer, in this Journal, vol. vii, p. 532, May, 1874, under the name *Stylinodon mirus*, as representing a new genus and species. The affinities of this new form, so far as then determined, were recorded as follows:

"These specimens resemble in some respects the corresponding parts of the genus *Toxodon* Owen, from the Quaternary of South America; but may, perhaps, have some more affinities with the Edentates."

The writer subsequently made this new form the type of a distinct family, the *Stylinodontidae*, and placed it under the order *Tillodontia* (this Journal, vol. ix, p. 221, March, 1875), and this reference, instead of the original suggestion as to its affinities with the Edentates, has been generally followed.

Fragmentary remains of the genus *Stylinodon* were subsequently obtained by the writer from time to time, in essentially the same horizon, but none of them threw much additional light on the affinities of this peculiar form. A fortunate discovery, in the spring of 1882, at a new locality, was a considerable part of the skull and skeleton of a second specimen apparently of the same species, and this material seemed sufficient to determine definitely the systematic position of *Stylinodon*, as soon as the specimen could be fully prepared for investigation. Owing to a pressure of other work, it was not until ten years later that this specimen was ready for the artist, and careful drawings made, when the Edentate affinities of the animal became more strongly apparent. The problem, however, was not a simple one, and the relation of the genus to other allied forms required careful consideration.

In an interesting paper recently published, Dr. J. L. Wortman discusses the affinities of this family, and presents an argument in favor of their being true Edentates.* This announcement makes it more important that the type specimen of the genus *Stylinodon* be figured, and that the second more perfect specimen be also illustrated and described, and this is the main object of the present communication.

* Bulletin American Museum of Natural History, vol. viii, pp. 259-262, 1896.

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The Skull and Teeth.

Figures 1 and 2, below, represent respectively a portion of a large front incisiform tooth of the lower jaw of *Stylinodon*, and several of the adjacent molar series, all natural size, and pertaining to the original type specimen of *Stylinodon mirus*. The peculiar sculpture of the enamel of the anterior tooth, showing both the longitudinal grooves and the transverse lines of growth, is a characteristic feature of these teeth. In the molars, the two bands of enamel, external and internal, show markings similar, but less distinct. The large front tooth is apparently from the left side, the enamel shown being thus on the outer face. The other specimen containing the molar teeth is part of the right lower jaw, with the inner face removed, showing the base of the teeth. The sockets of six of these are represented in figure 2, and behind them one more may be seen in the inner part of the jaw, making together seven in this series, all of similar form and size. The lower jaw containing these eight teeth was short, deep, and massive, with a strong coronoid process, the base of which was in advance of the posterior teeth.

In the second specimen of *Stylinodon* already mentioned, the lower jaws agree in all respects with the type. The seven molar teeth have the same position and proportions as in that specimen. The roots of the large incisiform teeth extended backward as far as the base of the penultimate molars. The condyle of the lower jaw is massive and transverse, the articulation looking upward. Its motion was not limited by a postglenoid process. The posterior margin of the jaw above the angle is thickened into a distinct process, which is somewhat incurved. The lower jaw is especially deep below the last molars, and the entire ramus is robust. The teeth of this genus and the great depth of the jaw below the last molars will distinguish it from *Dryptodon*, described by the writer from a lower horizon.

The skull of *Stylinodon* is short and massive. The temporal fossæ are especially large, and are separated above by a high ridge. The brain cavity was small. The occipital plane is narrow, and the sides converge above and meet at the junction with the sagittal crest. The occipital condyles are small, and there are no distinct paroccipital processes.

The Vertebrae.

The cervical vertebræ of *Stylinodon* are well shown in figure 3, below, which represents the series in the natural position essentially as found. The centra are very short, with the articular faces nearly flat. The axis has a long neural spine directed backward, but the succeeding cervicals have only rudimentary spines, as indicated in the figure.

The first dorsal vertebra has a very high, strong spine, as shown in figures 3 and 4. The other anterior dorsals have also elevated neural spines, and nearly flat articular faces on the centra.

The Scapular Arch.

The scapula of *Stylinodon* is narrow, with the acromion projecting but slightly below the glenoid fossa, as shown in figure 5. The posterior border is not expanded. The anterior portion is somewhat wider than the posterior, and there is no coracoid process. There is a well-developed clavicle. This is of moderate size, with the shaft somewhat flattened. It articulated above with the lower end of the acromion, and below with the sternum, but is not represented in the figures.

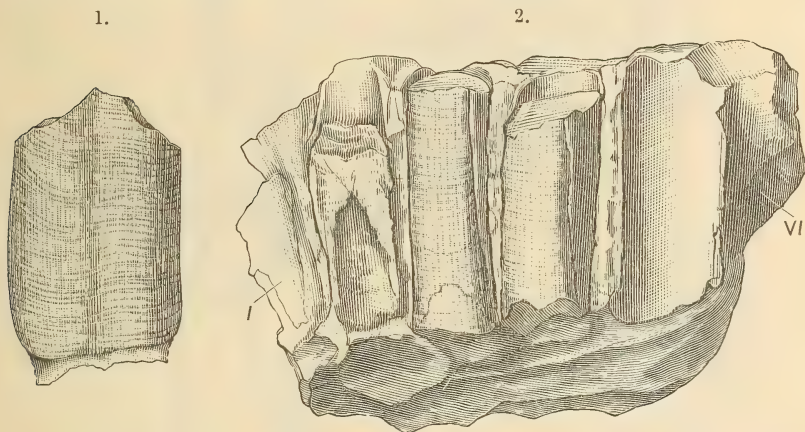


FIGURE 1.—Left incisiform tooth of *Stylinodon mirus*, Marsh; outer view.

FIGURE 2.—Molar series of right lower jaw of same individual; inner view.

I, socket of first premolar; VI, socket of penultimate molar.

Both figures are natural size.

The Fore Leg.

The fore leg of *Stylinodon mirus*, as represented in the second specimen above mentioned, is shown in figure 5, one-fourth natural size, with the scapula (*s*), the whole nearly in the position in which it was found. The humerus (*h*) is seen in this figure from the outside, and its connections above and below are clearly indicated. As this bone is especially characteristic, both of the genus and to a certain extent of the order, it is important to present here all its typical features.

3.

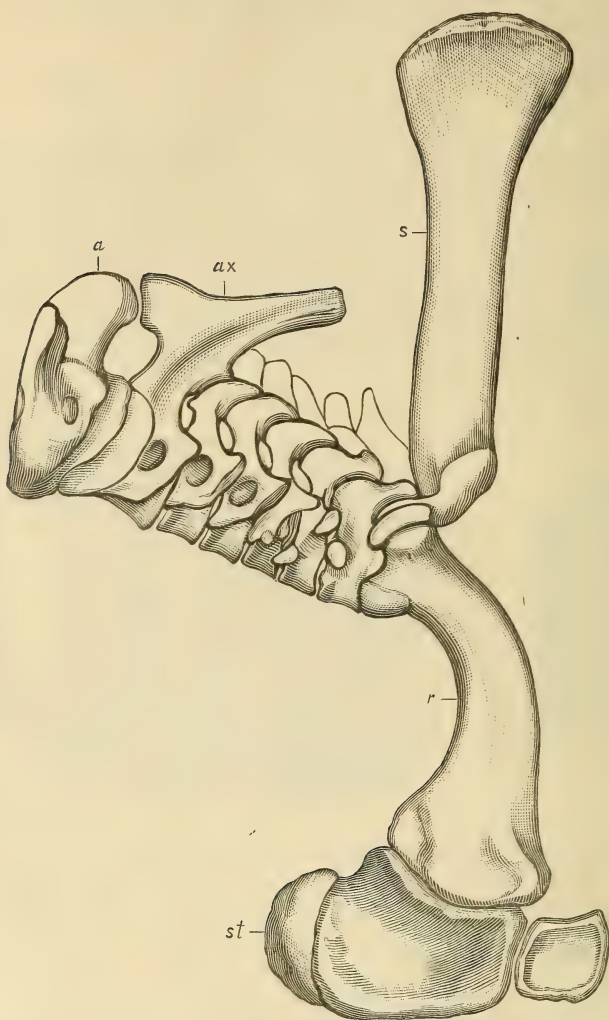


FIGURE 3.—Cervical vertebræ of *Stylinodon mirus*, with first dorsal vertebra, rib, and sternum, in position; seen from the left. One-half natural size. *a*, atlas; *ax*, axis; *r*, rib; *s*, spine of first dorsal vertebra; *st*, sternum.

These are seen to good advantage in figures 6 and 7, where the bone is represented one-half natural size. These figures render a detailed description unnecessary. This bone, like all those of the skeleton, is solid, there being no medullary cavity.

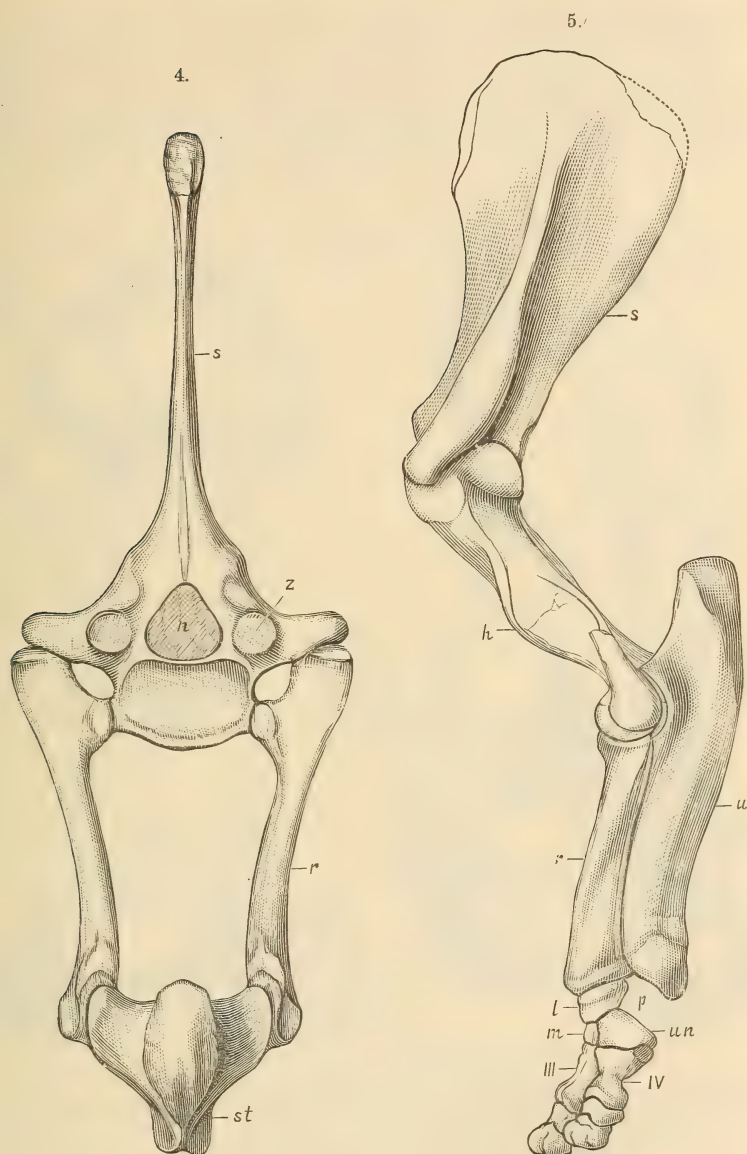


FIGURE 4.—First dorsal vertebra of *Stylinodon mirus*, with ribs and sternum in position; front view. One-half natural size.

n, neural canal; r, rib; s, spine; st, sternum; z, anterior zygapophysis.

FIGURE 5.—Left fore leg of same individual; outside view. One-fourth natural size.

h, humerus; l, lunar; m, magnum; p, place for pyramidal; r, radius; s, scapula; u, ulna; un, unciform; III, third metacarpal; IV, fourth metacarpal.

The inner structure of the shaft is shown in figure 7, *b*. The peculiar head of this humerus, with its strong tuberosity, the prominent deltoid ridge, and the supinator crest below, together with the supracondylar foramen and distal articulation, are all characteristic features, and taken together clearly indicate the Edentate nature of the animal to which this bone belonged.

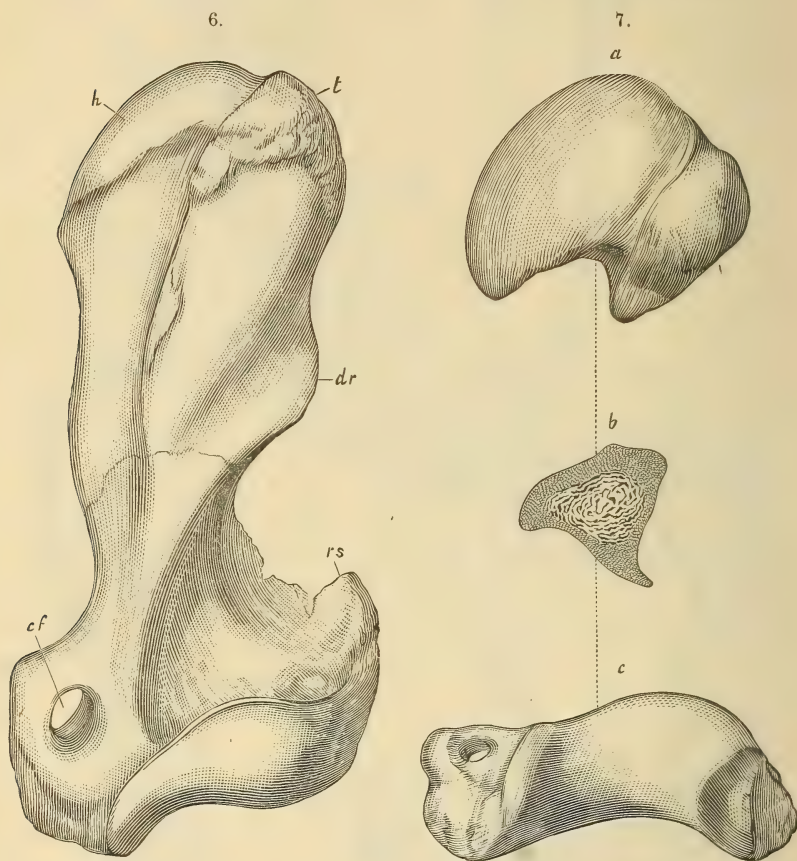


FIGURE 6.—Left humerus of *Stylinodon mirus*; front view.

cf, supracondylar foramen; *dr*, deltoid ridge; *h*, head; *t*, external tuberosity; *rs*, supinator ridge.

FIGURE 7.—Ends and section of same bone.

a, proximal end; *b*, transverse section; *c*, distal end.

All the figures are one-half natural size.

The radius and ulna are shown in position in figure 5. The radius (*r*) is much the smaller bone, and is placed nearly in front of the ulna (*u*). The latter is quite robust, and has a strong, powerful olecranon process, as shown in the figure. These bones also are Edentate in type.

The bones of the carpus and manus of this individual are only in part preserved, but those represented in figure 5 will serve to indicate the general nature of the fore foot. There were apparently five digits in this foot, although the fifth was small or rudimentary. The metacarpals were quite short, as indicated by the third and fourth. The phalanges were also short, and the median ones, at least, possessed claws.

The above description and figures of *Stylinodon* will in themselves be conclusive evidence to most anatomists that this genus has close affinities with the Edentates, if it is not a typical member of that group. Its relation to other allied genera will be discussed in a later communication.

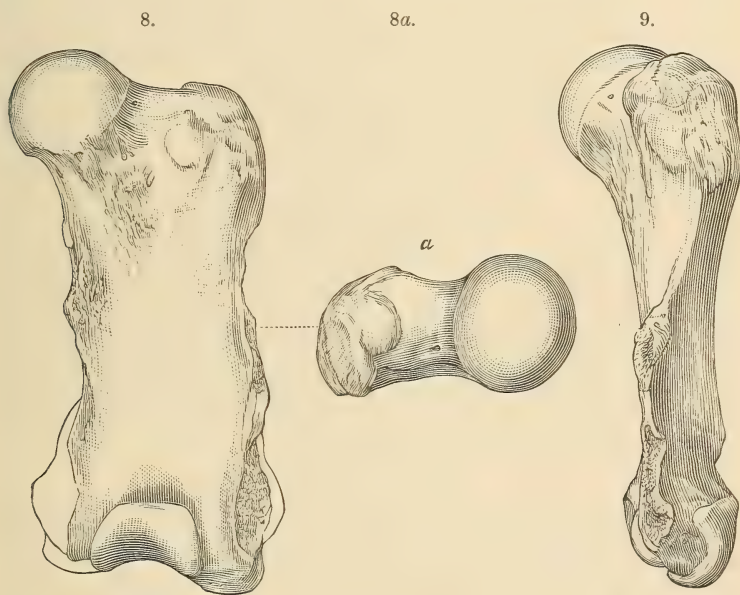


FIGURE 8.—Left femur of *Morotherium gigas*, Marsh; front view.

FIGURE 8a.—Proximal end of same bone.

FIGURE 9.—The same bone; outer view.

All the figures are one-sixth natural size.

The reference in the original description of *Stylinodon* to its resemblance with *Toxodon* is also worthy of some consideration, as the latter genus is now believed to be nearly related to various forms long considered Edentates, but at present regarded by many as aberrant Ungulates, since, notwithstanding the apparent resemblance of the feet to those of Edentates, the teeth indicate affinities with the perissodactyles.

This peculiar group, the *Chalicotheria*, of which *Chalicotherium*, Kaup, is the type genus, is now known to have its

representatives in America, Europe, and Asia. One genus, *Ancylotherium*, from the Miocene of Greece, was described by Gaudry as an Edentate. The term *Ancylopoda* derived from this genus has been recently used for the whole group, but, as the writer has already suggested, should be replaced by the name *Chalicotheria*.*

To this group, the genera *Moropus* and *Morotherium*, described by the writer as Edentates,† have been recently referred by some authors not familiar with the specimens on which these genera were based. While it is possible that the nature of some of the remains attributed to the former genus may be fairly in doubt, there can be no question that the two known species of *Morotherium* are both true Edentates. The type specimen of the latter genus is well represented in figures 8 and 9, above. It was mainly the remains of these two genera that suggested to the writers some important conclusions as to the early history of Edentate mammals, which are in part quoted below, since they seem to have been overlooked by recent writers.

Origin of the Edentates.

The affinities of the *Stylinodontia* as now determined have brought up again a most interesting question as to the origin and former geographical distribution of the Edentates, and it may not be out of place to repeat here what the writer said on this subject nearly twenty years ago, in an address before the American Association for the Advancement of Science, at the Nashville meeting, August, 1877.‡ The main passages relating to the Edentates are as follows:

“The Edentate mammals have long been a puzzle to zoölogists, and up to the present time no clew to their affinities with other groups seems to have been detected. A comparison of the peculiar Eocene mammals which I have called the *Tillodontia*, with the least specialized Edentates, brings to light many curious resemblances in the skull, teeth, skeleton, and feet. These suggest relationship, at least, and possibly we may yet find here the key to the Edentate genealogy. At present, the Tillodonts are all from the lower and middle Eocene, while *Moropus*, the oldest Edentate genus, is found in the middle Miocene, and one species in the lower Pliocene.” * * *

*The term *Ancylopoda* is preoccupied, having been used by Gray, in 1848, for a group of Brachiopoda.

† This Journal, vol. vii, p. 531, May, 1874; and vol. xiv, p. 249, September, 1877.

‡ Introduction and Succession of Vertebrate Life in America. This Journal, vol. xiv, pp. 338-378, November, 1877.

"The Edentate Mammals are evidently an American type, and on this continent attained a great development in numbers and size. No Eocene Edentates have been found here, and, although their discovery in this formation has been announced, the identification proves to have been erroneous. In the Miocene of the Pacific coast, a few fossils have been discovered which belong to animals of this group, and to the genus *Moropus*. There are two species, one about as large as a tapir, and the other nearly twice that size. This genus is the type of a distinct family, the *Moropodidæ*. In the lower Pliocene above, well-preserved remains of Edentates of very large size have been found at several widely-separated localities in Idaho and California. These belong to the genus *Morotherium*, of which two species are known. East of the Rocky Mountains, in the lower Pliocene of Nebraska, a large species apparently of the genus *Moropus* has been discovered. The horizon of these later fossils corresponds nearly with beds in Europe that have been called Miocene. In the Post-Pliocene of North America, gigantic Edentates were very numerous and widely distributed, but all disappeared with the close of that period. These forms were essentially huge sloths, and the more important were *Megatherium*, *Mylodon*, and *Megalonyx*." * * *

"It is frequently asserted, and very generally believed, that the large number of huge *Edentata* which lived in North America during the Post-Pliocene were the results of an extensive migration from South America soon after the elevation of the Isthmus of Panama, near the close of the Tertiary. No conclusive proof of such migration has been offered, and the evidence, it seems to me, so far as we now have it, is directly opposed to this view. No undoubted Tertiary Edentates have yet been discovered in South America, while we have at least two species in our Miocene, and, during the deposition of our lower Pliocene, large individuals of this group were not uncommon as far north as the forty-third parallel of latitude, on both sides of the Rocky Mountains. In view of these facts, and others which I shall lay before you, it seems more natural to conclude, from our present knowledge, that the migration, which no doubt took place, was from north to south. The Edentates, finding thus in South America a congenial home, flourished greatly for a time, and, although the larger forms are now all extinct, diminutive representatives of the group still inhabit the same region." * * *

"The Edentates, in their southern migration, were probably accompanied by the horse, tapir, and rhinoceros, although no remains of the last have yet been found south of Mexico.

The mastodon, elephant, llama, deer, peccary, and other mammals, followed the same path. Why the mastodon, elephant, rhinoceros, and especially the horse, should have been selected with the huge Edentates for extinction, and the other Ungulates left, is at present a mystery, which their somewhat larger size hardly explains." * * *

"I have already given you some reasons for believing that the Edentates had their first home in North America, and migrated thence to the southern portion of the continent. This movement could not have taken place in the Miocene period, as the Isthmus of Darien was then submerged; but, near the close of the Tertiary, the elevation of this region left a much broader strip of land than now exists there, and over this the Edentates and other mammals made their way, perhaps urged on by the increasing cold of the glacial winters. The evidence to-day is strongly in favor of such a southern migration. This, however, leaves the Old World Edentates, fossil and recent, unaccounted for; but I believe the solution of this problem is essentially the same, namely, a migration from North America. The Miocene representatives of this group, which I have recently obtained in Oregon, are older than any known in Europe, and, strangely enough, are more like the latter and the existing African types than like any of our living species. If, now, we bear in mind that an elevation of only 180 feet would close Behring's Straits and give a road thirty miles wide from America to Asia, we can easily see how this migration might have taken place. That such a Tertiary bridge did exist, we have much independent testimony, and the known facts all point to extensive migrations of animals over it."

The discoveries made within the last two decades, or since the above was written, have added much to a knowledge of the subject here discussed, but have not modified materially the conclusions given in the foregoing quotations. In regard to the origin and distribution of the Edentates, present evidence tends to confirm the opinion there recorded, that this great group of peculiar mammals originated in North America, and migrated to other parts of the earth, where their remains have since been found, or their living representatives still exist.

Yale University, New Haven, Conn., January 19th, 1897.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Diffusion of Metals.*—In his Bakerian lecture ROBERTS-AUSTEN has given the results of some elaborate experiments showing the tendency of two or more metals to mix spontaneously and thus to form a homogeneous mass. Already in 1883, he had observed that “while molten copper and antimony interpenetrate but slowly, the mobility of gold and silver in molten lead is comparatively rapid.” In his later experiments molten lead and bismuth were selected as the fluids into which the diffusion of the other metals took place. The tubes containing this molten metal, which were about 200^{mm} long and 10^{mm} internal diameter, were arranged in an air bath with double walls, which could be readily maintained at fixed temperatures, determinable accurately by means of thermoelectric junctions. To avoid convection currents the tubes were kept hotter at top than at bottom. After a suitable time, varying from six hours to seven days, the diffusion tubes were removed, cooled, carefully measured and cut into transverse sections; the contents of each section being weighed and analyzed. Kelvin, as a deduction from Fourier’s theory of heat-conduction, states the law of diffusion as follows: “The rate of augmentation of the ‘quality’ per unit of time is equal to the diffusivity multiplied into the rate of augmentation per unit of space of the rate of augmentation per unit of space of the ‘quality.’” By “quality” is here meant the concentration of the diffused matter. Hence the law may be represented by the differential equation

$$dv/dt = k(d^2v/dx^2)$$

where x is distance in the direction of diffusion, v is the degree of concentration of the diffusing metal, t the time, and k the diffusion constant; *i.e.*, the number which expresses the quantity of the metal in grams which diffuses through unit area (one sq. cm.) in unit time (one day) when unit difference of concentration (in grams per cubic cm.) is maintained between the two sides of a layer one centimeter thick. Since the unit of diffusivity has the dimensions [L^2T^{-1}] the diffusion constants may be expressed in square centimeters per day. Each pair of metals has a perfectly definite constant of diffusion at a given temperature. On tabulating the results obtained it appears that gold diffuses more rapidly in bismuth and in tin than in the heavier metal, lead, as also does platinum; the diffusion of both being about equally increased when bismuth is replaced by lead. Platinum diffuses more slowly in lead than gold does, while rhodium diffuses almost as rapidly; suggesting that the platinum metals are molecularly more complex than gold or silver.

The second part of the research was devoted to the question whether gold would still permeate lead if the temperature were maintained far below the fusing point of the latter metal. In the first experiments, thin plates of gold were fused to the lower ends of cylindrical rods of lead 14^{mm} in diameter and 70^{mm} long, and these cylinders were maintained for thirty-one days in a little iron chamber lined with asbestos and kept at 250°C , 75° below the melting point of lead. The cylinders were then measured, cut into sections and assayed. Gold was found through the entire length of the cylinder, the diffusivity being in one case 0.023 and in another $0.03^{\text{sq cm}}$ per diem. At 200° , the experiment lasting only ten days, the values were 0.007 and 0.008 . Since the eutectic alloy of gold and lead fuses at 200° , experiments were made to see if gold would diffuse into solid lead at 165° , a temperature below this point. The diffusivity was found to be 0.005 and $0.004^{\text{sq cm}}$ per diem. Even as low as 100° , the diffusivity was found to be 0.00002 . Experiments were also made on the diffusion of gold into solid silver at 800° ; a temperature 160° below the fusing point of silver and 50° below that of the eutectic alloy of these metals. The results gave a diffusivity of the same order as that of gold in lead at 200° .—*Phil. Trans.*, clxxxvii, A, 383-415, 1896.

G. F. B.

2. *On Optical Rotation in the Crystalline and the Liquid States.*—The specific rotation of several uniaxial crystals which polarize circularly, has been examined by TRAUBE, in connection with the rotatory power possessed by them in the melted or dissolved states. Thus the hexagonal-trapezohedral-tetartohedral crystals of patchouli camphor have a rotation for the D line of -1.325° per mm. in the optic axial direction; while in the fused state the specific rotation $[\alpha]_D = -118^{\circ}$ and in alcoholic solution $[\alpha]_D = -124.5$. Since these values correspond to rotations of -1.240° and -1.308° per mm. respectively, it follows that this camphor has practically the same specific rotation in the crystalline and amorphous states. The same is true of ordinary camphor. Matico camphor on the other hand, although crystallizing in the same system, gives a rotation of -1.877° for the D line, in plates 1^{mm} thick; while the melted substance has the specific rotation $[\alpha]_D = -29.17^{\circ}$. Hence the rotatory power is about six times as great in the crystalline as in the melted state. Rubidium tartrate crystallizes in the hexagonal-tetartohedral system, the crystals of the dextrotartrate being laevorotatory and those of the levotartrate being dextrorotatory. Plates 1^{mm} thick rotate 10.12° to 10.24° for the sodium line; while in aqueous solution and for a thickness of 1^{mm} the rotation is only 0.69° and of the opposite sign to that of the crystals. Cæsium dextrotartrate is isomorphous with the rubidium salt, the crystals giving a rotation of -14° to -19° per mm. for the D line; this rotation being opposite in sign to that of the aqueous solution.—*Ber. Ak. Berl. x*, 195-205, 1895; *J. Chem. Soc.*, lxx, ii, 509, September 1896.

G. F. B.

3. *On the Electrolysis of Water.*—The electromotive force required for the electrolysis of water was shown by v. Helmholtz to depend upon the density of the oxygen and the hydrogen at the electrodes, being lower in proportion as this density is smaller; so that if all gas be removed from the liquid, its value must be zero. From an equation connecting the electromotive force of polarization A , for any given pressures of the oxygen and hydrogen p_o and p_h , with the electromotive force when the pressure is the pressure of the atmosphere p_a , he has determined the value A_a to be 1.783 volts. SOKOLOFF has sought to obtain a direct proof that water can be decomposed with any electromotive force however small. For this purpose he used a voltameter containing two platinum plates, an insulated platinum point being placed near each plate. On passing a current, the electrodes became polarized by gas layers of definite density. Since these gases are electrically neutral and therefore free, they diffuse through the liquid, reach the platinum points, and polarize them also. By using a sensitive electrometer, the author has shown that any electromotive force, however small, can effect the electrolysis. Moreover, he finds that an electromotive force of one volt suffices to produce gas having a measureable pressure. In one experiment, which lasted 16 months, a calomel cell (1.072 volt) produced gas of 2.53^{mm} pressure; and this even seems not to be the limiting value, as the pressure continued to increase. Similar difficulties were met with here to those encountered in ordinary electrolysis. Forces are active on the surfaces of the electrodes which hinder the free diffusion of the gases and bring about the absorption of these gases by the platinum and other metals. Hence the accurate determination of A_a is not easy. Measurements at low pressures gave the author a value of 0.745 volt for A_a ; a value much smaller than that given by v. Helmholtz.—*Wied. Ann.*, II, lviii, 209–248, June, 1896. G. F. B.

4. *On the Electrolytic Production of Hypochlorites and Chlorates.*—The electrolysis of solutions of potassium chloride has been investigated by OETTEL. The current from four storage cells was passed through (1) a copper voltameter for measuring its strength, (2) an electrolytic gas voltameter, (3) the cells for the experiments, (4) an ampere meter, and (5) a resistance box. The electrodes of the gas voltameter were of nickel rolled into two concentric cylinders, and immersed in solution of caustic soda. The experiment cell had a capacity of about 115^{cc} and was closed tight by means of a rubber cover. Through this cover passed the wires to the electrodes, both being of platinum, a capillary delivery tube and another glass tube reaching to the bottom of the cell, by means of which it could be filled or emptied. The current strength employed was from 1 to 1.2 ampere, and it was continued for two hours. Using neutral solutions, the author finds that the main product is hypochlorite, 83 per cent of the active chlorine existing in this form at the end of the experiment, and 17 per cent as chlorate. Addition of

alkali, since it favors the decomposition of the water, increases the amount of chlorate formed. Raising the temperature acts similarly. Diminishing the density of the current at the kathode favors the reduction of the hypochlorite, the effect being greatest in a strong solution either neutral or slightly alkaline. At the anode, however, such a diminution increases the amount of water decomposed, the effect being less marked in a strongly alkaline solution. Since in an alkaline solution the reduction is a minimum, no diaphragm is necessary.—*J. Chem. Soc.*, lxx, ii, 517, September, 1896.

G. F. B.

5. *On the Action of Nitrous acid in a Grove cell.*—It has been observed by IHLE that if the nitric acid in a Grove cell be gradually diluted with water, the electromotive force remains nearly constant until the acid contains 38 per cent of HNO_3 . On further dilution, the electromotive force falls from 1.8 to 0.7 volt, having the lower value with 28 per cent nitric acid. If, however, potassium nitrite be added to the 28 per cent nitric acid, the electromotive force rises to 1.8 volt again, but falls to 0.7 volt when the nitrous acid present is destroyed by potassium permanganate, hydrogen peroxide, carbamide, etc. Conversely the electromotive force of an acid stronger than 38 per cent is lowered by the addition of permanganate or of carbamide. It is evident, therefore, that nitrous acid is the real depolarization agent in a Grove cell.—*J. Chem. Soc.*, lxx, ii, 554, October, 1896. (See the author's paper in *Zeitschr. physikal. Chem.*, xix, 577, May, 1896.)

G. F. B.

6. *On the Spectra of Fused Salts of the Alkali Metals.*—Because of the comparative simplicity of the spectra of the alkali metals, DEGRAMONT finds the salts of these metals to offer special advantages for the study of the line spectra of the non-metals by the action of a highly condensed spark on the fused salt. The spectrum thus obtained differs considerably from that obtained with the metal itself or that given with the fused salt and a non-condensed spark. Chlorides, bromides and iodides decompose readily under these conditions; while fluorides show but little tendency to dissociate, and carbonates, though dissociated with difficulty, give the spectra of the metals in their simplest form, no lines of carbon being observed. Salts of sodium show three intense double lines 6160–6154, 5895–5889, 5867–5862, the other lines being weak, though 5675, 5669, 5155, 5152, and a broad nebulous band 4983–4978, are discernable. Salts of potassium show 7698, 7665, 6939, 6911, 6308, 6245.5, 6117.5, 5832, 5811, 5801, 5783, 5360, 5344, 5340, 5323, 5113, 5099, 4828, 4389, 4309, 4264, 4223, 4185 and 4045. Lithium salts give 6706, 6103, 4972, 4603, 4273, 4132; the small number of lines making the salts of this metal particularly well suited for studying the spectra of the non-metals. When fused phosphates are subjected to the action of the condensed spark in this way, a line spectrum of phosphorus is obtained superior to that seen in a Plücker tube. Using the potassium or sodium salt, the following lines appear: 6506 (dif-

fuse) 6458, 6088, 6042, 6034·5, 6025, 5498·5, 5462 (feeble) 5453 (feeble) 5423·5, 5409, 5385, 5340, 5311, 5292, 5250, 4968 (diffuse) 4941, 4603, 4588·5. The triplet in the red 6042-6034·5-6025, and the doublet in the blue 4603-4588·5 are the most distinctly recognized lines.—*C. R.*, cxxii, 1411, 1534, June, 1896. G. F. B.

7. *On the Preparation of Lithium and Beryllium.*—The following mode of preparing lithium and beryllium has been described by BORCHERS. In the case of lithium the solution of the chlorides of the alkalis and alkali earths is made slightly alkaline, evaporated in an iron vessel, fused with ammonium chloride to render it neutral, and electrolyzed with a current of 1,000 amperes per square meter of cathode surface, the electromotive force being 5 volts. The upper rim of the iron crucible is kept cool by a circulation of cold water, so that a thin crust of solid material is formed on the surface which prevents the metallic lithium from coming to the air. The metallic globules are placed in a paraffin bath at 130°–200° when the pure metal rises to the surface. Solutions of beryllium chloride are evaporated down with an alkali chloride and ammonium chloride and electrolyzed in the same way as magnesium chloride. Calcium and magnesium chlorides must not be present. If the temperature be not kept as low as possible, the beryllium forms an alloy with the iron of the crucible.—*J. Chem. Soc.*, lxx, ii, 520, September, 1896. G. F. B.

3. *Light of the glow beetle.*—H. MURAOKA has studied the light given by a large collection of the "Johanniskäfer" and has found some interesting relations between this light and the effects of the radiation from uranine salts observed by H. Becquerel. The chafer or beetle used by the author constitutes one of the sights of Kyoto, Japan. About the middle of June one sees thousands of these beetles lighting up the environs of the towns. The experiments were conducted with over 300 of these chafers confined over the experimental sensitive plates by means of a net. It was discovered that the natural light of the chafer resembles ordinary light; but on filtration through cardboard or through copper plates the radiations exhibit phenomena similar to those observed by Becquerel, and also phenomena analogous to the Röntgen rays. The filtered rays manifest an extraordinary phenomenon (das Saugphänomen) which is analogous to the behavior of the magnetic force lines toward iron. The peculiarities of the filtered glow-beetle rays appear to depend upon the physical character of the substance through which they are filtered—perhaps its density. The peculiar phenomena observed are obtained by filtration. In an analogous way can X-rays be obtained by filtration—and this process suggests a means of rendering such rays homogeneous. The filtered glow-beetle rays show clearly reflection. It is difficult to show refraction, interference and polarization, yet the author believes that these phenomena are present. The filtered rays of this insect appear to occupy, like the fluorescence rays of Becquerel, a mean position between the

ultra-violet rays and the Röntgen rays.—*Ann. der Physik und Chemie*, No. 12, pp. 773-781. J. T.

9. *Röntgen Rays.*—In some recent experiments conducted in the physical laboratory of the University of Glasgow by Lord KELVIN, assisted by J. C. Beattie and M. Smoluchowski de Smolan (*Nature*, Dec. 31, 1896), it was shown that air drawn through an experimental tube in which it was exposed to the radiation from a Crookes tube became electrified, sometimes positively, and sometimes negatively. Professor Richard Threlfall and James A. Pollock (*Phil. Mag.*, Dec. 1896) conclude from careful experiments that no sensible amount of matter is projected from a Crookes tube, and that the hypothesis that the action of the X-rays is due to a projection of matter is untenable. They also conclude that the phenomenon is not due to the projection of ether streams, and that no disturbance of the ether is caused which is sufficient to affect electromagnetic radiations. J. T.

10. *Electric light in Capillary tubes.*—O. SCHOTT has observed the extraordinary brilliancy of electric discharges through very fine capillary tubes. The discharges were excited by an induction coil of 25^{cm} spark length. If one makes the assumption that the duration of the spark discharge is no longer than $\frac{1}{10,000}$ of a second, a capillary of from one to two square millimeters in section radiates as much light as 1—2000 Hefner flames emit. Since the ordinary arc light has a much larger radiating surface, the capillary light is far more powerful than is created by any other source.—*Ann. der Physik und Chemie*, No. 12, p. 768-772. J. T.

11. *Temperature of the sun.*—W. E. WILSON and P. L. GRAY have established (*Phil. Trans. Acad.*, vol. clxxv, 1894, p. 361), that the radiation of platinum up to the point 1600° C. obeys the law $q = a(T^4 - T_0^4)$, in which T is the absolute temperature of platinum, T_0 the absolute temperature of the surrounding medium. They have now deduced another formula, $q = b(T^3 - T_0^3) + a(T^4 - T_0^4)$, which, with suitable choice of the constants a and b , represents the radiation of polished platinum or blackened platinum. The authors find by extrapolation in their formula that the temperature of the hottest portion of the positive carbon attains a temperature of 3300° C. The radiation of the hottest portion of the positive carbon is nearly three times as great as that from the hottest portion of the negative carbon. Liking the sun to a black body, in respect to radiating power, the authors find that the temperature of the sun should be in the neighborhood of 8000° C.—*Proc. Roy. Soc., London*, vol. lviii, p. 24, 1895. J. T.

12. *Argon and helium.*—LOCKYER has examined the spectra of the gas obtained from uraninite or cleveite, bröggerite, and divers other minerals, and cites various cases in which lines are obtained in certain gases which do not appear in other gases, and concludes that argon and helium are mixtures of which the separation will be very difficult. He has also compared the wave-lengths of the lines of argon with the wave-lengths of lines

observed in the chromosphere, and in the nebula of Orion. A great number of these lines are identical, and this fact appears to throw a new light upon the numerous lines in the sun and the fixed stars the origin of which has been obscure. Argon and helium apparently establish a close connection between the elements of our planet and those of the other celestial bodies. When the intensity of the electric discharge through the gas from uraninite is augmented, carbon lines are rendered more feeble and others stronger. The author believes that this phenomenon indicates that the gas is a mixture. If one passes the discharge for a long time through helium, the yellow luminescence disappears. This results from the products of the combination of platinum which are decomposed when one afterwards heats the discharge tube.—*Proc. Roy. Soc.*, vol. lviii, 1895, p. 67, 113, 116, 192, 193.

J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *U. S. Geological Survey*.—The seventeenth annual report of the director, C. D. Walcott, gives a full account of the operations of the survey for 1895 and 1896 (pp. 200). There were 32 geological, 6 paleontological, and a still larger number of topographic parties in the field distributed through the United States from Alaska to Florida.

Shaler continued work upon the Narragansett coal field. Emerson was engaged in mapping central Massachusetts; Dale, the adjoining portions of Vermont and New Hampshire; and Hobbs, the Cornwall district of Massachusetts. Wolff and Clark in New Jersey; Keith in Maryland; Taft, Darton and Campbell in the Virginias; and Hayes in the southern Appalachians, continued geological mapping and completed a number of sheets. Eldridge studied the phosphates of Florida, and the gilsonite of Utah; David White continued his work on the coal-bed floras and his results are proving very valuable in identifying coal horizons. Van Hise, aided by Bayley, Smyth and others continued areal work in the Lake Superior region. Gilbert was in Colorado and Kansas; R. T. Hill in Texas; Weed in Montana. Emmons, assisted by Spurr and Tower, surveyed the Aspen mining district and made a reconnaissance into Montana and Idaho; Cross mapped the Telluride district of Colorado; R. C. Hills continued the survey of the coal and iron areas of south central Colorado. Turner and Lindgren were in the gold belt of California; Branner and Lawson in the San Francisco region; Diller in northwest Oregon; and Willis in northwestern Washington. Becker and Dall studied the gold and coal of the coastal regions of Alaska. Chamberlin, assisted by Salisbury, Leverett and others, continued his glacial investigations. Stanton studied the paleontology of the Cretaceous of Texas; Ward, the paleobotany of the Cretaceous and Jurassic of California; Knowlton of the Denver basin, while

the director himself did field work in Massachusetts, North Dakota, Montana, Idaho and Washington.

Separates of four accompanying papers in the seventeenth annual report have already been issued,* "The underground waters of the Arkansas Valley in eastern Colorado" (pp. 51), by G. K. Gilbert, "Geological reconnaissance in northwestern Oregon" (pp. 80), by J. S. Diller, "The Uintaite (Gilsonite) Deposits of Utah" (pp. 41) by G. H. Eldridge, and "The Water Resources of Illinois" (pp. 147) by Frank Leverett.

Monograph XXV, "The Glacial Lake Agassiz," (pp. 658) by Warren Upham, is a culminating publication of many papers. It contains, besides numerous maps, a full account of the facts and of Mr. Upham's views concerning them, and also a brief statement (pp. 244-251) of some alternative views by Prof. Chamberlin.

Six bulletins have appeared since July†: "The Catalogue and Index of contributions to North American Geology," 1732-1891; Bulletin No. 127 (pp. 1054), by N. H. Darton; and the "Bibliography and Index of North American Geology, Paleontology, Petrology and Mineralogy" for 1892-3; Bulletin No. 130 (pp. 210), for 1884; Bulletin No. 135 (pp. 141), and for 1895, Bulletin No. 146 (pp. 130), all three by F. B. Weeks, are invaluable aids to the working geologist, and their prompt publication by the survey is especially commendable.

Florence Bascom, in Bulletin No. 136 (pp. 124), on "The Ancient Volcanic Rocks of the South Mountain, Pennsylvania," described an acid and basic series of pre-Cambrian lavas. M. E. Wadsworth and G. H. Williams have advocated the volcanic origin of similar rocks at a number of points in the Atlantic states from Maine to Georgia, but this is the first full presentation of the facts from a single region (see further, p. 160).

F. H. Newell, in Bulletin No. 140 (pp. 356), gives the report of progress in the division of hydrography for 1895, and records stream measurements in many states and territories.

A brief contribution to the geology and paleontology of northwestern Louisiana, Bulletin 142 (pp. 63), by T. Wayland Vaughan, considers the Cretaceous, Tertiary and Pleistocene of that region and describes twelve new species of mollusks.

C. D. Perrine, in Bulletin No. 147 (pp. 22), notes the earthquakes in California in 1895. About forty shocks are recorded by the seismographs of the Lick Observatory. Bulletins Nos. 68, 96, 112, 114, and 129 contain records for previous years.

The following folios have been issued:

No. 26, Pocahontas, Va., lat. 37° to $37^{\circ} 30'$, long. 81° to $81^{\circ} 30'$, by M. R. Campbell.

No. 27, Morristown, Tenn., lat. 36° to $36^{\circ} 30'$, long. 83° to $83^{\circ} 30'$, by Arthur Keith.

No. 29, Nevada City, Cal., by Waldemar Lindgren.

The maps in folio No. 26 show the distribution of twelve for-

* For notices of two of these papers, see pp. 155, 156.

† See this Journal, vol. ii, pp. 84, 303, 306, 395 and 456, 1896.

mations in the Carboniferous, nine in the Devonian and Silurian, and two in the Cambrian. Those in folio No. 27 show two in the Carboniferous, two in the Devonian, ten in the Silurian, and six in the Cambrian. Folio No. 29 contains the Grass Valley, Nevada City and Banner Hill special maps, all upon a scale of $\frac{1}{14,400}$. This important placer and quartz mining district, which is described in six folio pages of text, has already produced about 120,000,000 of dollars. The maps show Carboniferous, Jura-trias, Eocene and Pleistocene formations, besides eleven eruptives, as well as many quartz veins and auriferous gravel deposits.

J. S. D.

2. *A geological reconnaissance in Northwestern Oregon*; by J. S. DILLER. (From the Seventeenth Annual Report of the U. S. Geol. Survey. Part I.)—The author has given brief but clear accounts of the topography, the features of the coast range and of the Oregon coast, and notes of the work reported by previous authors. He describes the geological formations met with, consisting of slight traces of pre-Cretaceous rocks. He concludes that, contrary to previous opinions, "it is quite improbable that pre-Cretaceous sedimentary rocks form any considerable portion of the Coast Range in Oregon north of Coquille." Much the same statement may be made regarding the Cretaceous. "No certain Cretaceous rocks are known in the [Coast] range, and yet it is probable that they do occur where it joins the Klamath mountains. South of Roseburg a short distance along Myrtle Creek, are Cretaceous conglomerate sandstone and shales. . . . indicated by the form of Aucella and other fossils they contain" (p. 16).

A large tract of Eocene rocks forms the great mass of the coast range from near the Columbia to the Coquille. These rocks are of both igneous and sedimentary origin.

The tufas in the former contain fossils of Eocene age. The shales generally contain marine fossils and in several places coal has been discovered in them. They are named the *Arago beds* from Cape Arago, near which the coal-bearing strata have been known for several years through the observations of Prof. Thomas Condon. The upper part of the series are sandstones and have yielded Eocene fossils as determined by Dr. Dall. Oligocene, Miocene, Pliocene and Pleistocene deposits are distinctly recognized; and the author has shown the geological history of the region as indicated by evidences of erosion, elevation and depression and the relation of the several beds to each other. Special tribute is given to the contributions made by Professor Condon to the knowledge of the geology of Oregon.

In the second part, on economic geology, account is given of the coal fields and a few other mineral products of the region.

The age of the coal is in some cases known to be that of the Eocene formation (Pebble Creek, Cape Arago, Callahans, and north Fork of the Umpqua). In other places the coal occurs in beds known to be older than some Miocene beds. At Coos Bay

the age is somewhat uncertain, but the evidence seems to point to probable Eocene rather than Miocene age. H. S. W.

3. *The underground water of the Arkansas Valley in Eastern Colorado*; by G. K. GILBERT. (From the Seventeenth Annual Report of the U. S. Geol. Survey. Part II.)—This is an excellent piece of descriptive geology, adapted to the needs of those who will reap most benefit from it, i.e., the people living in the region described.

The author has used fossils as true "*Leitfossilien*," marks of the various formations in which they occur; and among them he has included a beautiful plate of "nodules of marcasite," characteristic of the lower part of the Timpas limestone. The ordinary well driller should be able, with the use of this essay, to locate any one of the formations passed through. The Dakota sandstone is said to be the only valuable source for artesian water in the region discussed, and much care is taken to demonstrate the depth underground and slope of this sandstone, by the aid of diagrammatic sections across the region in various directions, and by clear definitions, in simple but thoroughly scientific language.

H. S. W.

4. *The Geological Society of America*.—The ninth annual meeting of the Geological Society was held in Washington, D. C., December 29th, 30th and 31st. The following officers were elected for the ensuing year:—President, Edward Orton, Columbus, O.; 1st Vice-President, J. J. Stevenson, New York City; 2d Vice-President, B. K. Emerson, Amherst, Mass.; Secretary, H. L. Fairchild, Rochester, N. Y.; Treasurer, I. C. White, Morgantown, W. Va.; Editor, J. Stanley-Brown, Washington, D. C.; Councillors, J. S. Diller, Washington, D. C., W. B. Scott, Princeton, N. Y. The sessions were held in the Hall of the National Museum and were presided over by the President, Joseph Le Conte, Berkeley, Cal. Memorials of deceased fellows were read as follows:—of Robert Hay, by R. T. Hill; of Charles Wachsmuth, by Samuel Calvin; of N. J. Giroux, by R. W. Ells.

The following is a list of the papers presented for reading:

JOSEPH LE CONTE: The different kinds of earth-crust movements and their causes. (President's address.)

J. S. DILLER: Crater lake.

J. F. KEMP: The Leucite hills, Wyoming.

N. H. DARTON: Physiographic development of the District of Columbia region.

N. H. DARTON: Dikes in Appalachian Virginia.

FRANK LEVERETT: On the changes of drainage in the Ohio river basin.

C. WILLIAM HAYES: The solution of quartz under atmospheric conditions.

MARIUS R. CAMPBELL: Erosion at base level.

MARIUS R. CAMPBELL: The origin of certain topographic forms.

J. B. WOODWORTH: Homology of joints and artificial fractures.

ARTHUR KEITH: Notes on the structure of the Cranberry district in North Carolina

C. H. HITCHCOCK: Notes on the stratigraphy of certain homogeneous rocks.

J. B. WOODWORTH: Unconformities in Martha's Vineyard and Block Island.

ROBERT BELL: Evidences of northeasterly differential rising of the land along Bell river. (Read by title.)

GEORGE E. LADD: Surface tension of water as a cause of geological phenomena.

ERASMUS HAWORTH: Cementing materials of the Tertiary sands and gravels of western Kansas.

H. W. TURNER: The work of the U. S. Geological Survey in the Sierra Nevada.

J. W. SPENCER: Geomorphology of Jamaica as evidence of changes of level. (Read by title.)

RALPH S. TARR: The Cornell glacier, Greenland.

H. L. FAIRCHILD: Shorelines of lake Warren and of a lower water level in western-central New York.

G. K. GILBERT: Old tracks of Erian drainage in western New York.

ANGELO HEILPRIN: The assumed glaciation of the Atlas mountains of Africa.

FRANK LEVERETT: The relation of an abandoned river channel in eastern Iowa to the western edge of the Illinois ice lobe.

GEORGE H. BARTON: Glacial observations in the Umanak district, Greenland.

F. B. TAYLOR: The Nipissing-Mattawa river, the outlet of the Nipissing great lakes.

F. B. TAYLOR: Moraines of recession and their significance in glacial theory.

HARRY FIELDING RIED: Mechanics of glaciers—moraines and stratification.

HARRY FIELDING RIED: Variations of glaciers.

BAILEY WILLIS: Preliminary note on the Pleistocene history of Puget sound.

WARREN UPHAM: Modified drift in St. Paul, Minnesota.

I. C. RUSSELL: Note on plasticity of glacial ice. (By title.)

CHARLES R. KEYES: Physical basis for general geological correlation. (By title.)

F. D. ADAMS and A. E. BARLOW: Origin and relations of the Grenville-Hastings series in the Canadian Laurentian (with observations by R. W. ELLS.)

J. F. KEMP: The pre-Cambrian topography of the eastern Adirondacks.

J. E. WOLFF and A. H. BROOKS: The age of the white limestone of Sussex county, New Jersey.

JOSEPH F. JAMES: Notes on the Potsdam and Lower Magnesian formations of Wisconsin and Minnesota.

HENRY S. WILLIAMS: On the Southern Devonian formations.

I. C. WHITE: A complete oil well record in the McDonald field between the Pittsburgh coal and the Oil Sand. (Read by title.)

DAVID WHITE: The age of the lower coals of Henry County, Missouri.

HENRY B. KÜMMEL: Structure of the Newark formation of western New Jersey.

WILLIAM B. CLARK: The Upper Cretaceous formations of the northern Atlantic coastal plain.

T. W. STANTON and F. H. KNOWLTON: Notes on the stratigraphy and paleontology of the Laramie and related formations in Wyoming.

I. C. RUSSELL: Geology of northeastern Washington.

E. H. BARBOUR: A study of nature, structure, and phylogeny of *Dæmonelix*.

GEORGE P. MERRILL: Notes on rock-weathering.

HENRY B. KÜMMEL: New evidence on the origin of some trap sheets of New Jersey.

C. WILLARD HAYES and ALFRED H. BROOKS: The crystalline and metamorphic rocks of northwest Georgia.

ALFRED C. LANE: The grain of rocks.

G. PERRY GRIMSLEY: The origin and age of the gypsum deposits of Kansas. (Read by title.)

5. *Pre-Cambrian rocks and fossils.*—In a paper read in the geological section of the British Association, Liverpool Meeting, September, 1896, by SIR W. DAWSON, an abstract of which is published in the Canadian Record of Science, July, 1896, an account of the present state of knowledge regarding the pre-Cambrian stratigraphy is given. The base of the Cambrian is

fixed at the lower limit of the *Olenellus* fauna. With this it is proposed to include the *Protolenus* horizon of Matthew, which terminates below in a barren sandstone in both southern New Brunswick and Newfoundland.

Beneath this Cambrian system lies the *Etcheminian* system of Matthew, composed of red and greenish slates and a basal conglomerate, and containing no trilobites but fossils referred to Ostracods, Mollusks, Worms, Brachiopods, Cystideans, and Protozoa. The following formations are recognized as belonging to the Etcheminian system: viz. the Signal Hill series and Random Sound series of Newfoundland, the Keweenaw or Keweenawan series of Lake Superior, and the Chuar and Grand Canyon formations of Arizona. The author regards Algonkian as a term "unhappy in form and cause, and perhaps should be dropped." The Etcheminian is regarded as the earliest system of Paleozoic time.

Below the Paleozoic rocks are two systems of the Eozoic. The upper member, the *Huronian* system, is separated above and below by unconformities from the contiguous rocks. "Laminated bodies comparable with Eozoan, burrows of worms, spicules of sponges and indeterminate fragments referable to Algae or to Zoophytes," are reported from the rocks of this system. Rocks of the system are recognized in New Brunswick, Newfoundland, Lake Superior and Lake Huron, and also apparently in Colorado. The lower member of the Eozoic is named the *Grenvillian* system (the upper part of Logan's Lower Laurentian). The rocks of this system are found in the St. Lawrence and Ottawa valleys, in New Brunswick, the Adirondacks and eastern slope of the Appalachians. Among the rocks are found belts of limestone "associated with what seem to be altered sedimentary beds, and in places rich in graphite and in apatite." The fossils recognized in this system are said to be "Protozoan alone, represented by peculiar and gigantic forms, as Eozoan and Archæozoan, and some smaller types (Archæospherinæ)." H. S. W.

6. *Antiquity of man in Britain*.—The number of *Natural Science* for January, 1897, contains a note of recent discoveries by Mr. W. J. LEWIS ABBOTT of what are believed to be evidences of the existence of man in Britain at a much earlier period than that which has been previously assigned. The specimens in question are a series of flints which at least bear a striking resemblance to the work of man, and which were obtained from the Cromer Forest Bed at Runton. They were found there sticking in the iron pan. This Forest Bed is now usually regarded as forming the top of the Pliocene series, and contains forms of the cave-bear, rhinoceros, elephant, deer, and other mammals living and extinct. A detailed account of the specimens is promised for the February number.

7. *On the Age of the Lower Coals of Missouri*; by DAVID WHITE. (Abstract of a paper read before the Geological Society of America, Dec. 31, 1896.)—As the result of the study of the

composition, vertical range, and geographical distribution of the plants from the lower coals of Henry County, Mo. (*The Age of the Lower Coals of Henry County, Missouri*), David White concludes that the two approximate low coals, which occasionally rest on the eroded surface of the Mississippian series in that region, are slightly younger than the Brookville, Clarion, or Mazon Creek horizons of the northern bituminous fields, though they are perhaps not so young as the middle Kittanning coal. Thus the period of the erosion of the Mississippian appears to include the time represented by the lower portion of the Lower Coal measures and the Pottsville series, a succession of sediments attaining a thickness of twelve hundred feet in the anthracite regions, or over twenty-five hundred feet in the Virginian portion of the Appalachian trough. The plants from Missouri are found by Mr. White to be probably nearly contemporaneous with those of the D ("Marcy") vein of the northern anthracite fields, but are possibly slightly younger. Forty-two of the forty-three plant genera and nearly one-half of the species occurring in this county are also present in the European basins. A critical comparative examination of the American and of the European floras leads the author, who regards the species as generally synchronous and indicating continental conditions involving greater facilities for inter-migration than geologists generally admit, to consider the Henry County coals as partially contemporaneous with the Transition Series between the Upper and the Middle Coal Measures of Great Britain, and the Third or Upper Zone of the Valenciennes series in the Franco-Belgian basin, or as referable to the Geislautein beds near the top of the Westphalian (*Saarbrücker Schichten*) of the Rhenish district.

8. *The relation of the fauna of the Ithaca group to the faunas of the Portage and Chemung*; by EDWARD M. KINDLE. Bull. Am. Paleontology, vol. 2, No. 6; pp. 1-56, with two plates. Dec. 1896.—This is an admirable example of what can be done by an exhaustive study of the fossil faunas of a single restricted area. The author has taken as his thesis the determination of the disputed question whether the fauna of the Ithaca group should be ranked with the Portage or Chemung. He has given a concise review of previous discussions over the general and particular points involved.

He has collected the fossils from over 80 different stations in the locality representing the faunas under discussion, and has identified all the species, compared the fossils, tabulated their range upward and downward in the general section, thus strongly supporting by a compact scientific argument his conclusion that "the Ithaca fauna should be classed in the Portage epoch."

H. S. W.

9. *The Phosphate-Deposits of Arkansas*; by JOHN C. BRANNER. (Read before the Am. Inst. Min. Eng. at Colorado meeting, Sept. 1896.)—The author, late State Geologist of Arkansas, has presented in this paper a concise statement of the present

known facts regarding the phosphate deposits in Arkansas. They appear to be restricted in this region to the interval between Lower Paleozoic rocks and the Carboniferous, occupied also in part by the black shale, which has been considered to be of Devonian age. The author concludes that "we are reduced to the necessity of believing that this interval, with its phosphate-deposits, represents the slow accumulation of organic matter over a comparatively deep sea (not abysmal, however) during the upper Silurian and Devonian periods."

Mr. C. W. Hayes has already discussed the similar phosphate deposits occurring in the same interval in the central Tennessee rocks.*

It may be observed that the presence of rolled and rounded pieces of fish bones, fragments of osseous plates that were $\frac{1}{2}$ to $\frac{3}{4}$ in. thick, which occur among these phosphate nodules both in Arkansas and in Eastern Kentucky, as known to the writer of this note, fix the age of the deposit as not earlier than the Devonian era.

H. S. W.

10. *Die Leitfossilien, ein Handbuch für den Unterricht und für das Bestimmen von Versteinerungen*; von ERNEST KOKEN, pp. 1-848, with nearly 900 figures. Leipzig, 1896 (Tauchnitz).—This elaborate treatise must prove of great value to students of paleontology in Germany in facilitating the determination of fossils in the laboratory. But the fact that the characteristic fossils are European species, and from European faunas will prevent American students from getting from it the help they might otherwise gain. Still, the analyses made of the characters presented by the fossils of each grand division of invertebrates discussed and the orderly listing and description of the characteristics of the fossil faunas of Europe, will render the work of value in the American laboratory of paleontology whenever comparative geology is studied.

The volume is composed of two parts: the first "Paläontologische Uebersicht," gives general descriptions of the characters of fossils of the chief invertebrate types, followed by analytical tables of families and genera. The second part is "Die Leitfossilien," in which the genera are given under each class for each era, and the characteristic species of each genus selected are distinguished from each other by analytical descriptions and tables, thus bringing out with great distinctness the prominent observed features of the characteristic fossils of each horizon.

H. S. W.

11. *Ueber die neue geologische Uebersichtskarte der Schweiz*. 1: 500,000; von C. SCHMIDT. Extract from *Compte-rendus* in Congrès géologique international 6th Session, 1894, Zurich, pp. 352-360).—This brief report gives detailed account of the classification adopted for the series of deposits from the Alluvium to the Devonian and of the crystalline rocks.

12. *The ancient volcanic rocks of South Mt., Penn.*; by FLORENCE BASCOM. U. S. Geol. Surv., Bull. No. 136, Washington, 1896.

* 16th Ann. Rep. U. S. Geol. Surv., Part IV, pp. 620-623.

8°, 124 pp., 28 pl.—The perception of the importance of the fact that considerable areas of previously unrecognized ancient rhyolitic lavas occur along the Atlantic coast and in the Appalachian region is due to the late PROF. G. H. WILLIAMS, and to his keenness and enthusiasm we owe primarily the appearance of this memoir, and the one noticed in the following section. In the present work Miss BASCOM has selected a small and typical area and has studied it thoroughly in the field and the material collected with equal thoroughness in the laboratory. Especially in the study of the characteristic structures of these ancient acid lavas, the ways in which they have been altered and modified and the means and criteria by which they may be recognized, is the work a valuable one, which must serve as a model for investigators of such rocks. It is illustrated with a large number of excellent plates which add greatly to its value. It is impossible, in the brief limits of this notice, to do more than to call the attention of the petrographer (and geologist as well) to its importance.

L. V. P.

13. *The geology of the Fox Islands, Maine*; by GEO. OTIS SMITH. (Inaug. Diss. Johns Hopkins Univ., 1896.)—What has been said in the foregoing applies well to this, which is chiefly a study of a series of ancient lavas occurring off the coast of Maine. The geology of the islands has been mapped and the occurrence of a small, interesting area of the Niagara is described, in which 80 species of fossils have been found by Prof. Beecher. A variety of interesting acid volcanics have been carefully studied and the results given. The work contains one plate and an excellent map on a scale of a mile to the inch.

L. V. P.

14. *The Cell in Development and Inheritance*; by EDMUND B. WILSON, pp. 1-371. New York and London, 1896. (The Macmillan Co.)—The author has presented in brief compass and in a clear and lucid manner the principal facts of our present knowledge of the cell; its morphology, chemistry, physiology and development. Without entering into so full an exposition of the theory of the cell as is given by Hertwig, the chief points in its history are given. No endeavor is made to give an exhaustive account of the cell, but rather the attempt is made to consider, within moderate limits, those features of the cell that seem more important and suggestive to the student of development. The omissions are particularly noticeable on the botanical side of the subject. The book is fully illustrated by some original figures, and by a large number of reproductions of the classic figures which have been produced by the many workers in this branch of biology. Each chapter is provided with an ample list of the literature in which the subjects discussed are elaborated.

In the last chapter the chief theories of inheritance and development are defined and discussed.

In reply to the question, "What is the nature of the germ-plasm and how has it been acquired?" Prof. Wilson takes an agnostic position. He says, "The truth is that an explanation of

development is at present beyond our reach," and again: "But when all these admissions are made, and when the conserving action of natural selection is in the fullest degree recognized, we cannot close our eyes to two facts: first, that we are utterly ignorant of the manner in which the ideoplasm of the germ-cell can so respond to the play of physical forces upon it as to call forth an adaptive variation; and second, that the study of the cell has on the whole seemed to widen rather than to narrow the enormous gap that separates even the lowest forms of life from the inorganic world" (p. 330).

H. S. W.

15. *Tables for the Determination of Minerals by Physical Properties, ascertainable with the aid of a few Field Instruments.* Based on the System of Prof. Dr. Albin Weisbach, by PERSIFOR FRAZER, 163 pp. 1897 (J. P. Lippincott Co.).—The fourth edition of the Weisbach tables prepared by Prof. Frazer has recently been issued. A large amount of new material has been added and the tables have been adapted in other respects so as to make them even more useful than before to the student. These tables are now too well and favorably known to need more than this brief notice.

16. *Der Lichtsinn augenloser Tiere* von WILIBALD A. NAGEL. 8vo. 120 pp. Jena, 1896 (Gustav Fischer).—This memoir discusses at length the function of sight in eyeless animals. It begins with a lecture on the apparent paradox of "seeing without eyes." This is followed by an account of the author's interesting experiments showing that many animals are still sensitive to light and distinguish the direction from which it comes after the removal of the eyes. The concluding part discusses the theories of vision and perception of light in the lower animals.

17. *Additional information concerning the giant Cephalopod of Florida*; by A. E. VERRILL.—After the publication of the notice in the January number of this Journal, I received additional facts concerning this huge creature from Dr. Webb. He has also sent me photographs,* taken two days after it came ashore, giving four different views of it.

These photographs show that it is an eight-armed cephalopod, and probably a true *Octopus*, of colossal size. Its body is pear-shaped, largest near the broadly rounded posterior end. The head is scarcely recognizable, owing to mutilation and decay. Dr. Webb writes that a few days after the photographs were taken (Dec. 7th), excavations were made in the sand and the stump of an arm was found, still attached, 36 feet long and 10 inches in diameter where it was broken off distally.

This probably represents less than half of their original length, as the arms of *Octopus* generally taper very gradually and are often five or six times longer than the body. What looks like the remains of the stumps of arms is shown in the front view.†

* These were taken by Mr. Edgar Van Horn and Mr. Ernest Howatt, to whom my thanks are due for the proofs.

† I have had drawings made from the photographs of the front view and side-

The length, given as 18 feet, includes the mutilated head region. The photographs show that the "breadth," given in the first account as 10 feet, applies to the more or less divergent stumps of the arms (?) and the body taken together, as they lie on the sand. The body, itself, is almost 7 feet wide, and rises at its thickest part $3\frac{1}{2}$ feet above the sand in which it is partially imbedded. The body is not greatly flattened and probably had a diameter of at least 5 feet when living. The parts cast ashore probably weighed at least 6 or 7 tons, and this is doubtless less than half of its total mass when living.

This species is probably one of those upon which the sperm whale feeds regularly on the whaling grounds off our southern coast.

Whalers have told me, years ago, that sperm whales killed in that region often vomit great masses of cephalopod flesh, including sections of huge arms. One reliable whaling captain used to say that he had seen very large suckers "as large as a dinner plate" on such fragments of arms. The suckers of this Florida *Octopus* would have been as large as that, if they had the proportions to the arms and body usual in small species of *Octopus*.

This species is evidently distinct from all known forms, and I therefore propose to name it *Octopus giganteus*. It is possible that it may be related to *Cirroteuthis*, and in that case the two posterior stumps, looking like arms, may be the remains of the lateral fins, for they seem to be too far back for the arms, unless pulled out of position. On the other hand, they seem to be too far forward for fins. So that they are probably arms twisted out of their true position. This is, at any rate, the first gigantic Octopod that has been described or figured from actual specimens.

Note. Since the above was in type, I have learned that Dr. Webb had caused the sand around the monster to be removed, and by means of six horses and powerful tackle he has moved it higher up the beach. He says that the true length of the body is 21 feet. The head is mostly or entirely gone. The outer integument has dried to a firm mass several inches thick.

view, which will be published in the American Naturalist. The photographs themselves are not strong enough for reproduction, having been over-exposed.

A notice of this *Octopus*, written by me, was published in the New York Herald, Jan. 3d, but my signature was omitted without my consent. A figure, furnished and described by me as a restoration, was inserted without any explanation: it is needless to say that it does not closely resemble the mutilated remains.

OBITUARY.

GENERAL FRANCIS A. WALKER, President of the Massachusetts Institute of Technology, and for 9 years (from 1872 to 1881) Professor of Political Economy and History in the Sheffield Scientific School, died suddenly in Boston on the 5th of January at the age of fifty-six. So large a part of his active and varied life was devoted to the public service, and the leading facts of his career have been given so fully in other publications, that no detailed account of his life will be expected in this Journal. But as he was the first economist to be elected to the National Academy of Sciences, the first President of the American Economic Association, and the author of numerous widely-read and important books on economic subjects, some reference must be made to the scientific side of his career.

His economic work lay in three distinct lines. He was at once the leader of an economic movement, a theoretical economist, and a statistician. His name is chiefly associated in the popular mind with the movement for the establishment of international bimetalism by an agreement among the leading states. His attitude on this subject has frequently been misunderstood. He had no sympathy with the national bimetallic movement of the campaign of 1896 which aimed at the introduction of the free coinage of silver by the United States alone, but he followed in his views very closely those of Cernuschi and other European economists. As a theoretician his most important contributions to the science are his Law of Wages and his Law of Profits. The former was first suggested in his treatise on Wages, published in 1876, and more fully developed in his text book of Political Economy published in 1882. This theory stood in direct opposition to the wage-fund theory of an earlier period, and has had an important influence upon economic thought. His theory of profits established a close parallel between profits and rent, and held that, just as rent is the remuneration for special advantages in the way of land, so profits are remuneration for special advantages in the way of business ability. As a statistician Gen. Walker's most important work lay in the management of the ninth and tenth censuses, which he developed from a mere enumeration of the population into a great statistical investigation, reinforced by numerous special studies of the principal resources of the United States. He combined in a rare degree the logical mind of the scholar, the vivid style of the popular writer, and the organizing power of the administrator. His literary activity lay in many fields, and many departments of economic science will feel his loss.

H. W. F.

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WITH PLATE V.

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[FOURTH SERIES.]

ART. XVI.—*Crater Lake, Oregon*; by J. S. DILLER. With Plate V.

THE Crater lakes, Bolsena and Bracciana in Italy, Paven in France and Laach in Germany, besides numerous other examples in various parts of Europe, South and Central America and Asia, have long been known to science, but the one in the United States which, all things considered, is the most imposing of the series, has scarcely been mentioned in scientific publications and its very existence even appears to be generally unknown to persons interested in such features.

The Crater Lake of Southern Oregon is deeply set in the summit of the Cascade Range and is remarkable, not alone for its geological history, of which it contains some especially interesting chapters, but also on account of its geographic position and depth, its beautiful blue transparent waters and the grandeur of its completely encircling cliffs, affording no outlet.

The summit of the range at this point is broad, with gentle, canyoned slopes surmounted by numerous volcanic cones.

The rim of the lake, which is nearly circular, with an average diameter of six miles, rises a thousand feet above the general level of the range. Its outer slope is gentle and rather regular from 10° to 15° , but within, the descent to the lake is precipitous. In general the rim may be described as the hollow base of a very large but deeply truncated cone. Here and there, two to four miles from the crest upon the outer side, are cinder and lava cones, adnate to the great cen-

tral volcano. The crest of the rim varies in height from 6759 to 8228 feet above the sea, i. e. 520 to 1989 above the lake. Its prominences stand at the head of spurs radiating from the lake. Some of these ridges were formed by single streams of lava, but others result from erosion and are separated by deep canyons, such as those of Sand Creek and Sun Creek, which pass directly through the rim.

The rim is composed wholly of lava streams and beds of volcanic conglomerate, dipping away from the lake as shown by the accompanying figure. This is the normal composition and structure of the basal portion of a large volcano.

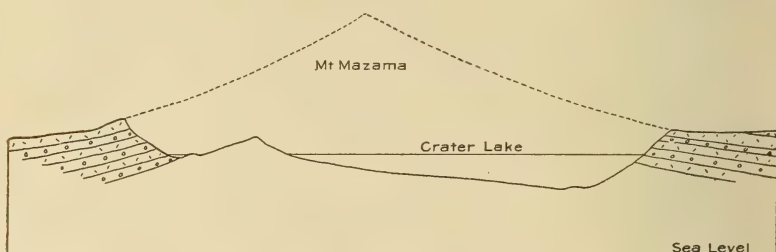


FIG. 1.—Section of Crater Lake and its Rim with the probable outline of Mt. Mazama, structural details generalized—vertical and horizontal scales the same.

The southern and western parts of the rim are made up of many beds; those of lava generally predominate, both in size and number. The northeastern portion of the rim at the Palisades is made up almost wholly of one great flow. The same is true to a less extent at Llao Rock, which is formed of a short but broad stream over 1200 feet in thickness. The exposures upon the inner slope of the rim show sections of the lava streams radiating from the lake, and that of Llao Rock furnishes a good example. Its greatest thickness is in the middle, where it fills an ancient valley, down the northwestern slope of the rim and tapers upon both sides to a thin edge as seen in Plate V. This massive flow rests locally on an irregular layer of pumice and is overlain by the same sort of material.

Andesites predominate, especially among the earlier lava flows so well exposed in section upon the inner slope of the rim; but rhyolites are common among the later ones, and are usually associated with pumice. Basalts were not observed in the rim. However, they occur upon its outer slope several miles away from the crest. They are connected with prominent cinder cones adnate to the once greater central peak and are the newest lavas of the region, excepting that of Wizard Island within the lake. This succession of lavas has been

observed in many large volcanoes and clearly points to Crater Lake as the site of such a mountain.

The rim is intersected by a number of vertical dikes, some of which stand out prominently upon its inner slope. The largest of these, locally known as the Devil's Backbone, varies from five to twenty-feet in thickness, and as seen in the plate, cuts the rim from water to crest one and a half miles southwest of Llaó Rock. Nearly a dozen other dikes appear in various parts of the rim, and all radiate more or less directly from the lake. Some of them cut through the older lavas only. Others reach to the top of the rim, but none was seen to penetrate the late flows of rhyolite. The dikes are of andesite, and their radial arrangement, as well as the succession of lavas, point to the middle portion of the lake as the center from which they emanated.

The name Crater Lake suggests that the lake occupies a crater, and it would naturally be supposed that the crater was originally as large as the rim of the lake. That this is not the case, however, is indicated by the following consideration.

No lava came out through the flanks of the rim excepting the basalts which are associated with cinder cones low on its outer slope. The lava streams generally reach up to the crest and radiate from the rim. If the crater were as large as the rim, the lavas must have escaped by overflow from its lowest point, and the inner slope of the rim would bear traces of the rise and fall of the lava within, instead of exposing sections of all the coulees and sheets of conglomerate of which it is made up. The inner slope of the rim is one of fracture and not of flow, and shows that the lava streams once extended farther towards the center of the lake than now and were more elevated in that direction. They issued from the crater or sides of a huge volcanic peak which once stood upon the present site of the lake.

The rim of the lake has been extensively glaciated and affords ample evidence concerning a change in the topography of the region since the glacial period. Moraines are widely spread over a large part of the rim, and extend in some cases far beyond it down the principal lines of drainage upon both sides of the range. The glacial debris is occasionally accumulated in well-defined ridges transverse to the direction of glacial motion, but more commonly is spread over the region in an irregular veneering composed of boulders, gravel and sand. From the main highway to the lake is a wagon road which ascends over a steep slope littered with many boulders and irregular piles of glacial debris. On the east of the road is the crest of the range. Against the rim of the lake this crest ends in a prominent moraine ridge marking the line of

separation between the glacial lobes which descended Anna and Castle Creeks on opposite sides of the range.

At many points on the very crest of the rim, glacial debris is well exposed, resting on striated rocks. Occasionally the debris is over 50 feet in thickness, but is rarely composed of large fragments. The largest boulders, about 10 feet in diameter, were seen some distance from the crest upon the outer side.

Glaciers descended all the valleys upon the outer slope of the rim for from two to five miles. Below, the moraines terminate in plains through which the present streams have cut narrow deep canyons with columned slopes or cliffs, rendering them inaccessible. Their sculptured walls gave name to Castle Creek, but an equally fine display occurs along Anna Creek.

Glacial striæ are well marked at many points, on the very crest of the rim, radiating down the outer slope in some cases for a distance of five miles. The slopes were so generally covered with moving ice that the outlines of the glaciers were not well marked. Probably the largest mass was that of the Divide glacier, which had a width of over four miles upon what is now the rim of the lake. The main portion descended Castle Creek and its branches toward Rogue River, but a large lobe extended down Anna Creek on the eastern slope of the range.

A large mass of ice descended the valley next south of Llao Rock, reaching far down over the broad stream of basalt from Red Cone. The lavas are deeply planed off and striated, but the effect of glacial erosion upon the general topography is not so marked as upon the southern side of the lake, where deep U-shaped canyons have been cut in the older lavas.

That the volcano was active at intervals during the glacial period is well shown by the glaciated flow of Round Top, upon the northeastern edge of the rim. This flow is overlain by two layers of pumice separated by a sheet of rhyolite, all of which were erupted after the glaciation of the surface upon which they rest.

The eruption must have been accompanied by great floods from the snow-capped mountain. Such floods would account for the fact that all the valleys radiating from Crater Lake have been extensively filled with sediments.

Reference has already been made to the occurrence of glacial striæ on the very crest of the rim. They may be seen in many places along the crest northwest of Victor Rock; also a few miles beyond, in the sag of the rim next southwest of Llao Rock, as well as near its summit. They occur also in Round Top, in Kerr Notch and over Eagle Crags, completing

the circuit of the lake from which they radiate. The topmost rocks of the crest are planed off and well striated upon the outer slope, but not upon the steep, broken surfaces which they present to the lake. Glaciation is a feature of the outer slope only, and it is evident that the ice armed with stones to scratch these rocks must have come from above, that is, from a peak which once stood upon the site of the lake.

In the deep, U-shaped canyons of Sun and Sand Creeks there is evidence to the same effect. They extend directly through the rim to the brow of the cliff, over 500 feet above the lake's surface, and belong to a system of drainage which has been completely decapitated. It is impossible to account for the glacial phenomena and drainage features of that region on the supposition that its topography is unchanged.

The succession of lavas and the system of dikes point to a volcanic center within the circle of the rim; but the structure of the rim, the condition of its inner slope and its glacial phenomena go a step further and suggest that during the glacial period the lake did not exist, and that its site was then occupied by a huge volcano which furnished the coulees and sheets of fragmental material in the rim, as well as the masses of ice and snow for its glaciation.

In figure 1, the probable outline of the peak is indicated. Judging from the character of the lava, the slopes of the rim, its size and the extent of its glaciation, it is reasonable to suppose that Mt. Mazama* was once a rival of Shasta and Rainier for the supremacy of the range.

The greatest feature of the region is the enormous pit or caldera containing the lake. It is 4,000 feet deep, extending from the crest of the Cascade Range down half-way to the sea-level. More than a square mile of its bottom is below the level of Klamath Lake, at the eastern base of the range. The pit is half concealed by the lake which so greatly beautifies the scene.

The volume of the pit is nearly a dozen cubic miles, and, if we include the lost peak, it would possibly be half again as large. The problem presented for solution by the removal of such an enormous mass and the development of so great a completely enclosed pit in the process, is one which has not yet been completely solved. There are, however, some phenomena about the lake that throw considerable light upon it, especially when taken in connection with those of similar features in other parts of the globe.

The composition and structure of the mass removed connects its transfer at once with volcanism, and the form of the

* The "Mazamas," a society of mountain-climbers of Portland, Oregon, met at Crater Lake last summer, and christened the mountain, whose remnant still encircles the lake, "Mt. Mazama."

remnants renders it necessary to suppose that it was either blown out by a tremendous volcanic explosion or swallowed up by an equally great engulfment.

The occurrence of a distinct rim at once looks favorable to the explosion method, for rims more or less complete, made up of the ejected materials, are known about many pits formed in that way.* As we have already seen, however, the rim is neither made up wholly or in any part of fragments blown out of the pit, but, on the contrary, is composed throughout of layers of solid lava, alternating with those of volcanic conglomerate and tuff, all of which were erupted from Mt. Mazama before the pit originated. There are, indeed, great quantities of pumice in the region, but that is, at least in part, clearly associated with the last eruptions of Mt. Mazama, for it underlies some of the latest flows, and differs widely from the material (andesite) of which the basal portion of that great volcano was made up. The entire lack, about the pit, of material corresponding in kind, form or quantity to that which would necessarily arise, if the pit were produced by a great explosion, compels us to look in the other direction for the solution of the problem.

While it is true, as shown by Lyell,† Scrope,‡ Judd,§ Geikie|| and others that the majority of crater lakes occupy basins produced by volcanic explosions alone, there are others, which the same authors recognize as occupying areas a portion of whose depression is attributed to subsidence. Lake Lonar in India has a low rim of fragmental material, but its volume is much less than that of the pit which it surrounds. For this reason the pit is ascribed chiefly to subsidence. Major Dutton¶ has pointed out a number of similar sunken areas or pits, but without lakes, in the Hawaiian Islands, and Dana has described** the sinking of the lava column (molten material), thus deepening the pit, in the yet active volcano of Kilauea. The subsidence of the molten material in the throat of the volcano and

* Volcanoes: The character of their phenomena, etc., by G. Poulett. Scrope, p. 215.

† Elements of Geology, sixth edition, pp. 679-82.

‡ Volcanoes, The character of their phenomena, etc. G. Poulett, Scrope, pp. 222-225.

§ Volcanoes, by J. W. Judd, pp. 170-171.

|| Text-Book of Geology, third edition, p. 240.

¶ Major Dutton who made a study of Crater Lake, after having visited the great volcanoes of the Hawaiian Islands, came to the conclusion that this depression was "formed in the same manner as the great calderas of the Hawaii Islands" (U. S. Geol. Survey, Eighth Annual Report, p. 158), that is, "by the dropping of a block of the mountain crust which once covered a reservoir of lava, this reservoir being tapped and drained by eruptions at much lower levels." (U. S. Geol. Survey, Fourth Annual Report, p. 105.)

** Characteristics of Volcanoes (1891) p. 127, and Manual of Geology, fourth edition, pp. 284-5.

consequent collapse of the floor of the pit with portions of the surrounding cliffs, are shown to result from the escape of the lava through fissures at much lower levels upon the slope of the mountain. In connection with the subsidence of the lava in Kilauea in 1840 a mass was erupted 27 miles from Kilauea and about 2700 feet below the summit of its cliff. In some cases, however, the sinking of the lava in Kilauea is not known to have been accompanied by an eruption of lava upon the surface.

The view that the caldera of Crater Lake originated by subsidence appears especially applicable for the reason that it occurs in the summit of a prominent range. The western slope of the range, although not steep, is considerably more inclined than that of Kilauea; and within 15 miles of the lake, the level of its deepest bed appears upon the surface. The engulfment of Mt. Mazama and the production of such an enormous pit in the process may well be expected to have given rise to eruptions upon the lower slopes of the range at no very great distance from the lake.

That Mt. Mazama actually disappeared by subsidence is plainly suggested by the behavior of the last erupted lava. It is a rhyolite which escaped from the north slope of Mt. Mazama. Its broad stream follows a shallow valley that now appears in the rim at the head of Cleetwood Cove. Upon the outer slope of the rim, opposite the cove, there is a long depression down the surface of the flow where cliffs, columns and angular blocks occur in great confusion. They have resulted from the caving in of the crust of the lava tunnel in the valley filled by the thickest portion of the flow. But on both sides the lava surface is smooth and easily traversed.

Upon the inner slope of the rim is an equally remarkable and exceptional feature. Descending from the Rugged Crest, at the upper end of the broken tunnel, to the lake is a flow several hundred yards in width. It is part of the large stream of rhyolite which spread upon the outer slope of the rim, and has flowed inwards towards the lake over the broken ends of the older coulees of andesite. The fluidal structure, as well as the parting planes produced by it, are well marked approximately parallel to the inner slope of the rim. It is the only inward-flowing lava found anywhere on the rim, and appears to indicate that before the thickest portion of the final flow of rhyolite had completely solidified, Mt. Mazama was engulfed, and the yet viscous lava followed it towards the abyss.

It might be supposed that a study of the features upon the bottom of the great pit would disclose the character of the change by which it was produced; but this is not the case. Its original surface is in large part, if not wholly, covered by

the products of later volcanic eruptions. We have an excellent opportunity to study this portion of the pit on Wizard Island, where the bottom rises above the surface of the water. The island, near the center of the view in plate V, is formed of a cinder cone and lava field, which are practically unchanged since their recent eruption.

The steep-sloped cinder cone, 845 feet in height, is surmounted by a perfect crater 80 feet in depth. The encircling lava field, made up of angular blocks of dark lava broken up at the time of the eruption, is rough in the extreme.

Judging from Wizard Island, one might expect that there were other piles of recent cinders and lava upon the bottom of the pit, and so it seems; for according to the soundings of the lake made by Captain, now Major, Dutton in 1886,* there are two such prominences rising from great depths, but failing by over four hundred feet to reach the surface of the water. The eruptions of lava and fragmental material upon the bottom of the pit have partially filled it up, but how much has been lost in depth by these final outbursts cannot be estimated.

To epitomise: The history of Crater Lake and its rim began in the upbuilding, by normal volcanic processes, of a large volcano, Mt. Mazama, comparable in the nature of its lavas, structure and size with the greater peaks of the Cascade Range.

Crater Lake did not then exist. Its site was occupied by Mt. Mazama, which was an active volcano in the glacial period. Glaciers descended from its higher slopes, scratching the rocks and depositing moraines about its base.

The later eruptions of Mt. Mazama occurred in the glacial period and doubtless produced extensive floods which filled with debris the valleys of all the streams radiating from the mountain.

In approximate connection with its final eruption, the molten material of the interior withdrawing, the summit of Mt. Mazama caved in and sank away, giving rise to a caldera nearly six miles in diameter and 4,000 feet deep. Thus originated the great pit in which Crater Lake is contained, encircled by a glaciated rim, the hollow base of the engulfed Mt. Mazama.

Upon the bottom of the caldera, volcanic activity continued. There were new eruptions building up cinder cones and lava fields and partially refilling the great pit.

Precipitation is greater than evaporation in that region. Volcanic activity ceasing, the conditions were favorable for water accumulation, and Crater Lake was formed in the pit.

Washington, D. C.

* Eighth Annual Report, Part I, pp. 157-8.

ART. XVII.—*On the Origin and Relations of the Grenville and Hastings Series in the Canadian Laurentian*; by FRANK D. ADAMS and ALFRED E. BARLOW, with remarks by R. W. ELLS.*

As the exploration of the more remote portions of the great Canadian protaxis of the North American continent progresses, accompanied by the detailed mapping of its more accessible parts, the true character, structure and origin of the Laurentian System is being gradually unfolded. The work of Logan during the early years of the Canadian Geological Survey, though excellent in the main, is being supplemented and, in certain directions, corrected; and as the work is now being pushed rapidly forward, it is believed that the time is not far distant when, difficult as the study is, we shall possess as complete a knowledge of these ancient rocks as we now do of many more recent formations. In a paper which appeared in 1893,† it was demonstrated that Logan's "Upper Laurentian" does not exist as an independent geological series, the anorthosites, which were considered as constituting its main feature, being in reality great intrusive or batholithic masses; while in a subsequent paper,‡ it was shown that in the remaining portion of the Laurentian, two distinct classes of rocks could be distinguished, the first being beyond all doubt igneous rocks, and the second consisting of highly altered rocks of aqueous origin. In addition to these two classes of rocks of which the origin could be recognized, there was yet a third class, concerning the genesis of which there remained some doubt.

Since the appearance of these papers, the present writers have been working together in mapping a large area (about 4800 square miles) of the Laurentian in central Ontario, comprising map-sheet No. 118, and a portion of 119, of the Ontario series of geological maps, the district lying to the north of Lake Ontario, along the margin of the Protaxis, and being especially well suited for purposes of study. Portions of three summers have already been spent in the district, and as two years more must probably elapse before the work can be completed, it is desired here to present a general outline of the results so far obtained, indicating certain conclusions which seem likely to be reached concerning the origin of the rocks in question.

The Fundamental Gneiss, as shown by the work of the Canadian Geological Survey, occupies by far the larger portion of the protaxis as a whole; while the Grenville Series has prob-

* Published by permission of the Director of the Geological Survey of Canada.

† Adams F. D.—Ueber das Norian oder Ober-Laurentian von Canada, Neues Jahrbuch für Mineralogie, Beilage Band viii, 1893.

‡ Adams, F. D.—A Further Contribution to our Knowledge of the Laurentian, this Journal, July, 1895.

ably its principal development along the southeastern margin, although as the exploration of this vast area is continued, new and possibly more extensive areas of these rocks may yet be found. Strata belonging to this series are already known to occur on the upper Manicouagan River, the lower Hamilton River, on the Manouan Branch of the Peribonka and on the lower part of the Ungava River, in the Labrador peninsula; while similar rocks, which would seem to belong to this series, but which have not as yet been thoroughly examined, have been met with about southern Baffin's Land, and possibly about Baker Lake near the head of Chesterfield Inlet, as well as on the west coast of Hudson Bay and also at Cross Lake on the Nelson River.

The Fundamental Gneiss consists of various igneous rocks closely allied in petrographical character to granites, diorites and gabbros, and which almost invariably have a more or less distinct foliation. Where this foliation is scarcely perceptible it becomes very difficult to decide whether the rock is an intrusive granite or diorite, or a very massive form of the gneiss in question. The different varieties of gneissic rock alternate with or succeed one another across the strike, or sometimes cut one another off, suggesting a complicated intrusion of one mass through the other, but there is usually a general direction of strike to which, in any particular district, the foliation of all the varieties conform. The associated basic rocks are very dark or black in color and are usually foliated, but sometimes this foliation is absent and the rock occurs in masses of all sizes and shapes scattered through the acid gneisses, and in the great majority of cases so intimately associated with the latter that it is impossible to separate the two in mapping. The smaller of these masses can be distinctly seen to have been torn from the larger, which latter are often of enormous size. This process can be observed in all its stages. The granitic gneiss invades the great basic masses, sending off wedge-like arms into them, which tear them apart and anastomose through them in the most complicated manner. These smaller masses can then be observed to be separated into still smaller fragments, which either from the fact that they split most readily in the direction of their foliation or owing to subsequent movements, when the rock was in a more or less plastic condition, often assume long ribbon-like forms. That great movements have taken place in the whole series during or after this invasion is shown by the complicated twisting of these darker bands and masses into all manner of curious and intricate forms, as well as in the frequent rolling out of great blocks of the amphibolite, after having been penetrated in all directions by small pegmatite veins, resulting in masses of a dark basic gneissoid rock, filled with strings, bunches, separated fragments or grains of quartz or feldspar, giving to the mass a pseudo-conglomeratic appearance.

There can be but little doubt that the various gneissic rocks, constituting the more acid part of the series, are of truly igneous origin; and there is no evidence whatever of their having ever formed part of a sedimentary series.

The true character of the more basic members is more uncertain, but they are probably closely related to the pyroxene granulites of Saxony, and doubtless represent either differentiation-products of the original magma, or basic intrusions whose structural relations and characters have been largely masked by the great movements which have taken place in the whole series at a later date.

The Grenville Series differs from the Fundamental Gneiss in that it contains certain rocks whose composition marks them as highly altered sediments. These rocks are chiefly limestones, with which are associated certain peculiar gneisses, rich in sillimanite and garnet, having a composition approaching ordinary shale or slate, or else very rich in quartz and passing into quartzite, having thus the composition of sandstone. These rocks, as has been shown in one of the papers before referred to, usually occur in close association with one another, and are quite different in composition from any igneous rocks hitherto described. They are considered as constituting the essential part of the Grenville series. They usually, however, form but a very small proportion of the rocky complex in the areas in which they occur, and which, owing to their presence, is referred to the Grenville series. They are associated with and often enclosed by much greater volumes of gneissic rocks, identical in character with the Fundamental gneiss. The limestones are also almost invariably penetrated by masses of coarse pegmatite, and occasionally large masses of the limestone are found embedded in what would otherwise be supposed to be the Fundamental gneiss. The whole thus presents a series of sedimentary rocks, chiefly limestones, invaded by great masses of the so-called Fundamental Gneiss, and in which, possibly, some varieties of the gneissic rocks present may owe their origin to the partial commingling of the sedimentary material with the igneous rocks by actual fusion. There is, however, no reason to believe, from the evidence at present available, that any considerable proportion of the series has originated in the last mentioned manner.

It will be readily seen that an exact delimitation of areas of the Grenville series is thus sometimes a matter of great difficulty, as they often appear to shade away into the Fundamental gneiss, and it has hitherto been difficult in the case of the Grenville series to account for the existence of such a comparatively small proportion of sedimentary strata, intimately associated with such great volumes of igneous gneisses.

The relations of the two series, as determined by the investigations of the last two seasons, throws new light upon the subject, and indicates the probable explanation of the difficulty.

The northwestern half of the more restricted area at present under consideration is underlain by Fundamental Gneiss, presenting the characters described above. A smaller area of the same gneiss occurs at the southwestern corner of the area, in the townships of Lutterworth, Snowdon and Glamorgan, while in the southern and southeastern portions of the area there are other occurrences, which, however, present a more normally granitic character.

The southeastern portion of the area is underlain by rocks of the so-called Hastings Series, consisting chiefly of thinly-bedded limestones, dolomites, etc., cut through by great intrusions of gabbro-diorite and granite. These limestones and dolomites are usually fine-grained and bluish or greyish in color, with thin interstratified layers, holding sheaf-like bundles of hornblende crystals. As compared with the limestones of the Grenville series they are comparatively unaltered. They form beyond all doubt a true sedimentary series, and in the southeastern corner of the area are associated with conglomerates or breccias of undoubtedly clastic origin. Between the great area of Fundamental Gneiss in the northwest, and the Hastings series in the southeast of the sheet, there lies an irregular-shaped belt of rocks, presenting the characters of the typical Grenville series as above described, the limestones having in all cases the form of coarsely crystalline, white or pinkish marbles, although more or less impure. The strike of the foliation of the Grenville series follows in a general way the boundaries of the Fundamental Gneiss, and is seen in an especially distinct manner to wrap itself around the long and narrow development of the gneiss exposed in the southwest corner of the area. Isolated masses of the limestone and gneiss characteristic of the Grenville series are also found in the form of outlying patches about its margin, as for instance in the townships of Lutterworth and Stanhope. The relations of the Grenville series to the Fundamental gneiss are such as to suggest that in the former we have a sedimentary series later in date than the Fundamental Gneiss, which has sunk down into and been invaded by intrusions of the latter series when this was in a semi-molten or plastic condition. The limestones, while themselves rendered more or less plastic by the same heat which softened the lower gneisses, do not show any distinct evidence of absorption or solution by the invading rocks, unless some of the highly garnetiferous gneisses usually associated with the limestones are formed by a commingling of the two rocks. Masses of the highly crystalline limestone or marble in some cases lie quite isolated in what are, to all appearances, the lower gneisses, as if they had been separated from the parent mass, and had passed outward or downward into the gneissic magma.

The contact of the Fundamental Gneiss and the Grenville series would appear therefore to be a contact of intrusion, in very many cases at least.

The question of the relations of the Grenville series to the Hastings series then presents itself. Although repeated traverses have been made from one series into the other, no sharp line of division has been found. Towards the southeast the limestones of the Grenville series in many places, though still highly crystalline, seem to be less highly altered, and finally, as the Hastings series is approached, present in places the bluish color of the limestones of the latter series; so that it is often impossible to determine to which series they should be referred. The limestones of both series also have the numerous small interstratified gneissic inclusions or bands so frequently referred to in the descriptions of the limestones of the Grenville series, making the resemblance still more complete. In fact, although the true relations of the two series are obscured by the presence of numerous great intrusions of granitic and basic pyroxenic rocks, and can only be determined with absolute certainty by the completion of the mapping, the investigations so far indicate that in the region in question the Hastings series would seem to represent the Grenville series in a less altered form. In other words, the Hastings series, when invaded, disintegrated, fretted away and intensely metamorphosed by and mixed up with the underlying magma of the Fundamental Gneiss, constitutes what has elsewhere been termed the Grenville series. The Grenville series may, however, represent only a portion of the Hastings series, and the work so far done in this district has not been sufficient to determine the stratigraphical position of this portion.

Concerning the age of the Hastings series but little is known as yet. To the southeast of the area under consideration, however, its clastic character is well marked, breccias and conglomerates, often greatly deformed by pressure, being present as well as certain fine-grained and comparatively unaltered limestones, in which a very careful search may yet be rewarded by the discovery of fossils. Both lithologically and stratigraphically the rocks bear a striking resemblance to rocks mapped as Huronian in the region to the north and northeast of Lake Huron, and it seems very likely that the identity of the two series may eventually be established. The two areas, however, are rather widely separated geographically, so that the greatest care will have to be exercised in attempting such a correlation.

Like the Grenville series, the rocks of the Hastings series are unconformably overlain by and disappear beneath the flat-lying Cambro-Silurian rocks of the plains, which limit the pro-taxis on the south and are separated from it in time by an immense erosion interval. Further investigation in this area, as well as in that adjoining to the east, now being mapped by Dr. R. W. Ells, will, however, it is hoped, before long throw additional light on the age of this very interesting and important series of rocks. If further investigation proves that the relations of the several series have been correctly diagnosed,

and that the explanation of these relations as given above is correct, the Laurentian system of Logan will resolve itself into an enormous area of the Fundamental Gneiss, which is essentially of igneous origin and which there is every reason to believe forms part of the downward extension of the original crust of our planet, perhaps many times remelted and certainly in many places penetrated by enormous intrusions of later date; into which Fundamental Gneiss, when in a softened condition, there have sunk portions of an overlying series, consisting chiefly of limestones.

Farther east, in that portion of the province of Quebec where the Grenville series was first studied by Logan, the rocks of the Hastings series proper have not been recognized. The Lower Paleozoic strata rest directly upon the Grenville series and would cover up the Hastings series to the south should it extend as far east as this. The limestones of the Grenville series, moreover, here extend much farther back from the edge of the protaxis in bands and streaks conforming to the strike of the underlying gneissic rocks, so that the origin of the series and its relations to the Fundamental Gneiss is not so clearly indicated. When, however, its relations here are interpreted in the light of the Ontario occurrences, there seems to be no reason why the same explanation might not be offered to account for its origin also. The bands of limestone, which often vary in thickness from place to place, and are frequently interrupted in their course or abruptly cut off, might be considered as having taken their form from long folds in the series from which they were derived as it settled down into the magma beneath, or as having been separated by great lateral intrusions of the gneissic magma. Their original shape and character has, however, without doubt been greatly altered by the enormous movements to which both series of rocks have been subsequently subjected.

If again this proves to be the true explanation of the relations of these series, the Grenville series will cease to be an anomaly among our Archæan formations and will, so far as its mode of occurrence is concerned, bear the same relation to the Fundamental Gneiss as the Huronian does farther west in the Lake Superior and Huron district, as shown by Lawson and Barlow; the similarity in position, however, not implying identity in age.

The recognition of the Grenville series as consisting of a series of sedimentary rocks, largely limestones, invaded by igneous material which now makes up by far the greater portion of the series and consists largely of extravasations of the Fundamental Gneiss, is now pretty certainly established by the field evidence. Its recognition as a portion of the Hastings series which has been intensely metamorphosed, will probably be more clearly established as the field work progresses. Since subordinate areas of the Grenville series also occur to the

south of the St. Lawrence in the Adirondack region, and are now being mapped, it will be of great interest to ascertain whether the same relations do not also exist in that area, and whether a continuation of the Hastings series to the south cannot be recognized in the "Huronian Schist" of St. Lawrence and Jefferson counties, shown upon the Geological Map of the State of New York, which has just been issued by the Geological Survey of this State.

It is perhaps unnecessary to draw attention to the fact that the recent investigations of Messrs. Wolff, Brooks, Nason, Kemp, Westgate and others on the crystalline limestones of New Jersey have a certain bearing on this subject.

Remarks by R. W. Ells :

In connection with the statements advanced in the preceding paper by Dr. Adams and Mr. Barlow, it is but right that the conclusions arrived at from the study of the similar rocks in their eastern and northern extension should be stated. The investigations in this quarter have now been carried on for six years, and have extended over a very large area to the north of the Ottawa, in which is included the typical Grenville series of Sir W. E. Logan, and extending far up the Gatineau River; while to the westward, the work has been carried on till the vicinity of the area, described in the accompanying paper, has been reached. It may be said therefore that the detailed examination of the rocks which make up the Grenville and Hastings series has extended over an area about 250 miles in length by 75 miles in breadth.

In the early days of the study of these rocks much difficulty was experienced. Firstly there was a great and almost inaccessible wilderness, the only available means of travel over the greater portion being by canoes; and in the second place there was an almost entire lack of trained observers to carry on the work. Add to this the entire absence of microscopical determinations, and one can readily comprehend the difficulty experienced in the attempt to solve this most difficult of the problems in Canadian geology.

Foliation and stratification were considered conclusive evidence of sedimentation, and as most of the rocks of the great Laurentian complex gave evidence of these forms of structure, the inference naturally followed that the greater portion of the gneissic, granitic and anorthositic rocks were of sedimentary origin. So far was this sedimentary theory carried out that, in the earlier reports of the Geological Survey, even the masses of binary granite and many of the pyroxenic rocks were included in the same category. This was at the time a very natural conclusion, since many of these masses have a regular bedded structure and conform, over very considerable areas, to the regular stratification of the rocks, either gneiss or crystalline limestone. As the country became more accessible the

field investigations showed very clearly the intrusive nature and later age of many of these masses, while the aid of the microscope fully established the non-clastic and igneous character of the great bulk of the gneisses. The more recent and probably sedimentary origin of the limestones and associated gneisses of the Grenville series, as distinct from the great mass of the underlying Laurentian Fundamental Gneiss, was pointed out some years ago in a paper by the author, read before the Geological Society of America. The subsequent investigations on these rocks, to the west and southwest, showed that the conclusions then presented were correct, but that as the work extended westward to the south side of the Ottawa the character of the various groups of rocks gradually changed. The areas of limestone became much more extensive, and there was a large development of hornblende and other dark-colored rocks, rarely seen to the north of the Ottawa. The limestones also were very often highly dolomitic, and in certain areas were blue and slaty, with but little of the aspect of the Grenville limestones, except where they were in close contact with masses of intrusive granite or diorite. There is also in the rocks of this group to the south of the Ottawa, where they have been styled the Hastings series, from the fact that they were first studied in the county of Hastings, a very considerable proportion of schists, micaceous, chloritic and hornblendic, with certain regularly slaty beds, and others of true conglomerate containing quartz pebbles. In certain portions the lithological resemblances between the Grenville and Hastings rocks are very close, and they may, for all practical purposes, be regarded as one and the same series. From a number of sections made in the counties of Renfrew on the south of the Ottawa, and in Pontiac, to the north of that river, it would appear that the original Grenville limestones and associated grey and rusty gneiss form the lower part of the series, since it is only on their development westward towards the typical Hastings locality that the characteristic Hastings schists and associated strata are met with.

In character and general aspect these rocks of the Hastings series are almost identical with many of those which in the Eastern Townships and in New Brunswick have been regarded as probably Huronian for many years; and so marked is the resemblance that the author, in presenting his summary report for 1894, referred the rocks seen near the Bristol iron mines to that division. It now appears very conclusively established that both in the eastern and western areas we have a well developed series of rocks, including limestones, gneiss and schists, which are of undoubted sedimentary origin, but which have been enormously acted upon by great intrusive masses as well as by other dynamic agencies, so that in many parts their original characters have almost entirely disappeared.

ART. XVIII.—*Outline of a Natural Classification of the Trilobites*; by CHARLES E. BEECHER. (With Plate III.)

[Continued from page 106.]

Arrangement of the Families of Trilobites.

SUBCLASS TRILOBITA.

Order A. HYPOPARIA.

- | | |
|----------------------|------------------------|
| Family 1. Agnostidæ. | Family 3. Trinucleidæ. |
| Family 2. Harpedidæ. | |

Order B. OPISTHOPARIA.

- | | |
|--------------------------|------------------------|
| Family 4. Conocoryphidæ. | Family 8. Bronteidæ. |
| Family 5. Olenidæ. | Family 9. Lichadidæ. |
| Family 6. Asaphidæ. | Family 10. Acidaspidæ. |
| Family 7. Proëtidæ. | |

Order C. PROPARIA.

- | | |
|-------------------------|------------------------|
| Family 11. Encrinuridæ. | Family 13. Cheiruridæ. |
| Family 12. Calymenidæ. | Family 14. Phacopidæ. |

The order Opisthoparia, with nearly one hundred and fifty genera, has a much greater geological distribution than either of the others, and was by far the dominant group during the Cambrian and Ordovician, being represented by about eighty-five genera in the former age and forty-five in the latter. Nineteen genera of this order are found in the Silurian and ten in the Devonian, most of them having continued on from older ages. Four genera represent the order in the Carboniferous and one in the Permian, thus marking the extinction of the subclass as well as the last genera of the Opisthoparia.

The comparative abundance and duration of the three orders are expressed in the table on page 182, from which it appears that the Hypoparia probably culminated in pre-Cambrian times, the Opisthoparia during the Cambrian, and the Proparia during the Ordovician.

In the following classification, the families adopted by Salter³² and Barrande³ are in the main adhered to, and the number corresponds very closely with that in Zittel's "Handbuch der Palæontologie"³³ and also in the "Grundzüge"³⁶ of the same author. The order of arrangement, however, is very different. A great number of family divisions have been proposed, and undoubtedly many others will yet be made, but it is not within the province of this paper to determine the precise value and

limitations of the families. This would require discussions of priority and synonymy, and otherwise detract from the direct purpose of the writer; viz., to establish a basis for a natural classification, and in this way to apply what is currently known and accepted regarding the trilobites. Nevertheless, some notice must be taken of several families and genera which for various reasons do not appear here. The family Aglaspidæ, including the genus *Aglaspis* Hall, proves to belong to the Merostomata, and is therefore omitted. The family Bohemilidæ has been shown by the writer⁶ to have no foundation, because the type of the genus *Bohemilla* Barrande was based upon a mutilated specimen of *Eglina*.

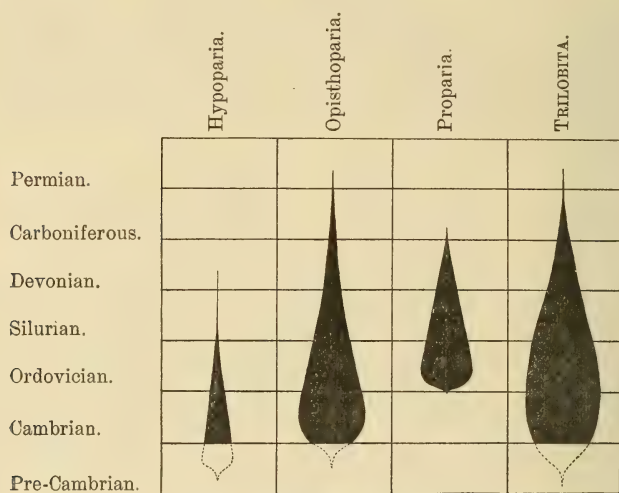


Table of Geological Distribution of Trilobites.

Several genera still commonly adopted are not here recognized in the lists under the families, since from the minute size of the individuals described and their immature characters, they must be considered as the young of larger forms. Such are *Conophrys* Callaway, *Cyphoniscus* Salter, *Holometopus* Angelin, *Isocolus* Angelin, and *Shumardia* Billings. *Trio-*
pus Barrande has been shown to be a chiton.

Much could be said against some of the recognized genera, but, as with the families, the writer has preferred in almost every case to adopt, for the present, what has been commonly accepted, and thus to avoid the entanglements of dates and synonyms which would be out of place in any general discussions. The type species of every genus is here made the central idea. It is taken as representing the genus more closely than any fortuitous assemblage of diverse species, which the

next investigator may show belong to another or to several genera. Our ideas of a genus are naturally based mainly upon the species with which we are most familiar. Until forced to make authoritative comparative statements, it does not occur to one that the type of the genus under consideration may be quite different. An American student's conception of *Homalonotus* will probably be formed largely upon the species commonly known as *H. delphinocephalus* Green, from the Niagara, and *H. DeKayi* Green, from the Hamilton. The first time the type of the genus, *H. Knighti* Murchison, is seen he will be puzzled to place it. Similar examples could be multiplied indefinitely, and only show that the type must be taken as the ultimate unit of comparison.

Diagnoses and Discussions of Orders and Families.

Order A. HYPOPARIA, n. ord.

(ὑπό under, and πᾶσις cheek piece.)

Free cheeks forming a continuous marginal ventral plate of the cephalon, and in some forms also extending over the dorsal side at the genal angles. Suture ventral, marginal, or submarginal. Compound paired eyes absent; simple eyes may occur on each fixed cheek, singly or in pairs.

Including the families Agnostidæ, Harpedidæ, and Trinucleidæ.

This order includes the groups C and D, or the *Ampycini* and *Agnostini* of Salter, and also the family Harpedidæ of that author, which he included in the *Asaphini*. The special recognition of characters, however, between Salter's groups and the order here proposed is different.

The presence of a part homologous with the free cheeks of other trilobites has generally been more or less overlooked in the families of this order. In *Trinucleus*, *Dionide*, and *Harpes*, the sutures have been correctly determined by Barande.³ Likewise, Angelin⁷ gave the right structure in *Ampyx*, but in *Agnostus*, this feature has escaped notice. The examination of extensive series of *Agnostus*, in the National Museum and in the Museum of Comparative Zoölogy,* has proved that under favorable conditions of preservation this genus shows a distinct plate, separated from the cranidium by a suture, and it can be compared only with the free cheeks in other trilobites,

* In the former, through the courtesy of C. D. Walcott and C. Schuchert, and in the latter, of A. Agassiz and R. T. Jackson.

especially where they are continuous around the front of the cephalon, as in *Trinucleus* and *Ampyx*. The presence of a hypostoma in *Agnostus* was also determined. Even in the higher genera of this order, the suture is frequently unnoticed in descriptions, but it can be seen in all well-preserved specimens. In *Trinucleus*³⁹ and *Harpes*, it follows the edge of the cephalon, and separates the dorsal from the ventral plate of the pitted limb. Since eye spots occur on the fixed cheeks in the young *Trinucleus* and adult *Harpes*, it is probable that this character is a primitive one in this order, and has been lost in *Agnostus*, *Microdiscus*, *Ampyx*, and *Dionide*.

The ontogeny of *Sao*, *Ptychoparia*, *Triarthrus*, *Dalmanites*, etc., shows that the true eyes and free cheeks are first developed ventrally, appearing later at the margin, and then on the dorsal side of the cephalon. Therefore, the Agnostidæ, Trinucleidæ, and Harpedidæ have a very primitive head structure, characteristic of the early larval forms of higher families. Other secondary features show that this order, though the most primitive in many respects, is more specialized than either of the others, except in their highest genera. The characters referred to are the glabella and pygidium. Very few species show the primitive segmentation of the glabella, it being usually smooth and inflated, and resembling in its specialization such higher genera as *Proetus*, *Asaphus*, and *Lichas*. The pygidium often fails to indicate its true number of segments. Some *Agnostus* and *Microdiscus* show no segments either on the axis or limb of the pygidium. *Trinucleus* and others may have a many annulated axis and fewer grooves on the pleural portions. The number of appendages corresponds to the axial divisions, as determined by the writer.⁴ The multiplication of segments in the pygidium and their consequent crowding makes them quite rudimentary.

Family I. AGNOSTIDÆ Dalman.

Small forms, having the cephalon and pygidium elongate, nearly equal, and similar in form and markings. Free cheeks ventral, continuous; suture marginal or ventral. Eyes wanting. Thorax composed of from two to four segments, with grooved pleura. Cambrian and Ordovician.

Including the genera *Agnostus* Brongniart, and *Microdiscus* Emmons.

The genera in this family are primitive in their form and structure, as shown by their ventral free cheeks, marginal or ventral suture, elongate cephalon, and large pygidium. Some

species have spines at the genal angles, corresponding to the interocular spines of *Holmia*, and young *Elliptocephala*, and not to the spiniform projections of the free cheeks. From their abbreviated thorax, and progressive loss of annulations on the glabella and axis of the pygidium, they must also be considered as degraded. *Microdiscus*, the earlier genus, has three or four free segments, and in some species (*M. speciosus* Ford) preserves the normal pentamerous glabella and annulated pygidial axis, while the later genus, *Agnostus*, has but two free segments, and has lost the annulations of both glabella and pygidium. Matthew²⁶ has described the protaspis stage of *Microdiscus*, which agrees with the similar stage of *Ptychoparia* and *Sao*.

Fully a dozen generic names have been proposed for forms of the general type of *Agnostus*, but none of them has ever come into current use. Nine were first published by Corda,¹⁸ but as Barrande³ subsequently showed that one was based on an *Orbicula*, another on a poor specimen of *Æglina*, and three others on a single species, this grouping soon fell into disuse. Moreover, Barrande was inclined to give no generic value to the form and lobation of the glabella, and therefore all the species were placed by him in the single genus *Agnostus*. At the present time, more weight is given to the characters of the glabella and pygidium, as indicating generic differences in dorsal and ventral structure, so that further study may show the desirability of restoring such of Corda's names as were founded upon natural groups of this family.

Family II. HARPIDIDÆ Barrande.

Cephalon large, margined by a broad expansion or limb; glabella short and prominent. Free cheeks ventral, continuous; suture marginal, following the outer edge of the limb. Paired simple eye spots, or ocelli, single or double, at the distal ends of well-marked eye lines on the fixed cheeks, extending outward from the glabella. Thorax of from twenty-five to twenty-nine segments, with long grooved pleura. Pygidium (in *Harpes*) very small, composed of but three or four segments.

Cambrian to Devonian.

Including *Harpes* Goldfuss, *Harpina* Novák, and *Harpides*? Beyrich.

The genus *Harpes* presents considerable variation in the lobes of the glabella. *H. ungula* Sternberg shows the full number of five lobes, but in some species, as *H. d'Orbignyianum*

Barrande, the structure is like *Cyphaspis*, with separate basal lobes. *Arraphus* Angelin was apparently based upon a specimen of *Harpes* denuded of the pitted border. *Harpides* Beyrich is imperfectly known but seems to belong here. The ocular ridges and tubercles on the fixed cheeks, the broad limb, the glabella, and the narrow weak thoracic segments are all in accord with *Harpes*, though in other features it has affinities with the Conocoryphidæ.

In many respects, *Harpes* is one of the most interesting genera of trilobites since it is so unlike other forms. The broad hippocrepian pitted limb of the cephalon has its counterpart in *Trinucleus* and *Dionide*, although not so well developed in these genera. The head is also comparatively longer and larger, both features being decidedly larval. It is the only family known in which functional visual spots, or ocelli, are situated on the fixed cheeks. The young *Trinucleus* has similar eye spots, or ocelli. The great number of free segments in the Harpedidæ is another primitive character, although the cephalon (in *Harpes*) still remains larger than the thorax and pygidium.

Family III. TRINUCLEIDÆ Barrande.

Cephalon larger than the thorax or pygidium; genal angles produced into spines. Free cheeks continuous, almost wholly ventral, carrying the genal spines; suture marginal or submarginal. Paired simple eyes or ocelli generally absent in adult forms; compound eyes wanting. Segments of thorax five or six in number, with grooved pleura. Pygidium triangular; margin entire; axis with a number of annulations; limb grooved.

Ordovician and Silurian.

Including the genera and subgenera *Trinucleus* Lhwyd, *Ampyx* Dalman, *Dionide* Barrande, *Endymionia* ? Billings, *Lonchodomus* Angelin, *Raphiophorus* Angelin, and *Salteria* ? W. Thompson.

The leading genera of this family form a tolerably homogeneous group, although each has sometimes been recognized as characterizing a separate family. *Trinucleus* and *Dionide* have a broad pitted border, but this hardly seems of sufficient importance to remove them far from *Ampyx*, since the three genera agree in nearly all important structural details, as the extent and character of the free cheeks, the glabella, the number of free segments, and the character of the pygidium. *Lonchodomus* and *Raphiophorus* of Angelin are commonly admitted as subgenera of *Ampyx*.

Both *Salteria* W. Thompson and *Endymionia* Billings have been described as subgenera of *Dionide* Barrande, though there is little positive evidence for this disposition of them. Until more perfect material representing these forms has been described, it will not be possible to decide satisfactorily upon their relationships or place in a classification. Therefore, they are left with doubt in the present family.

Order B. OPISTHOPARIA, n. ord.

(ὀπισθε behind, and πᾶρειά cheek piece.)

Free cheeks generally separate, always bearing the genal angles. Facial sutures extending forwards from the posterior part of the cephalon within the genal angles, and cutting the anterior margin separately, or rarely uniting in front of the glabella. Compound paired holochroal eyes on free cheeks, and well developed in all but the most primitive family.

Including the families Conocoryphidæ, Olenidæ, Asaphidæ, Proëtidæ, Bronteidæ, Lichadidæ, and Acidaspidæ.

This order is nearly equivalent to group B, or the *Asaphini* of Salter, which included also the families Calymenidæ and Harpedidæ, which belong elsewhere.

The families which are here placed under this order lend themselves quite readily to an arrangement based upon the characters successively appearing in the ontogeny of any of the higher forms. Thus *Sao*, *Ptychoparia*, and other genera of the Olenidæ have first a protaspis stage only comparable in the structure of the cephalon with the genera of the preceding order, the Hypoparia. Therefore this stage does not enter into consideration in an arrangement of the families of the Opisthoparia. In the later stages, however, there is a direct agreement of structure with the lower genera of this order. The nepionic *Sao*, with two thoracic segments (Plate III, fig. 2), has a head structure agreeing in essential features with that in *Atops* or *Conocoryphe* (Plate III, figs. 14, 15). A later nepionic stage, with eight thoracic segments (Plate III, fig. 3), agrees closely with adult *Ptychoparia* or *Olenus* (figs. 16, 17). These facts clearly indicate that the family Conocoryphidæ should be put at the base of this extensive order. Then, as *Ptychoparia* and *Olenus* are more primitive and simple genera than *Sao*, they, as typifying the family Olenidæ, should govern its position, which accordingly would be next after the Conocoryphidæ. In each case, a family is considered as represented by its typical and most characteristic forms. It would be impossible to

consider the advanced specialized genera of some families as representing their normal facies, for each one has undergone an independent evolution, and some characters have reached as great a degree of differentiation as will be found in much higher families.

It has been recognized that variations in the positions of the eyes, the relative size of the free and fixed cheeks, and the degree of specialization of the glabella have a definite order in the ontogeny of any trilobite, and also that these characters have a greater taxonomic value than many others. Applying these principles in arranging the families which come under the Opisthoparia, we have the sequence as indicated above, beginning with the Conocoryphidæ and followed by the Olenidæ, Asaphidæ, Proëtidæ, Bronteidæ, Lichadidæ, and Acidaspidæ, in regular progression. See Plate III, figs. 14-23.

Family IV. CONOCORYPHIDÆ Angelin.

Free cheeks very narrow, forming the lateral margins of the cephalon, and bearing the genal spines. Fixed cheeks large, usually traversed by an eye line extending from near the anterior end of the glabella. Facial sutures running from just within the genal angles, curving forward, and cutting the anterior lateral margins of the cephalon. Eyes rudimentary or absent. Thorax with from fourteen to seventeen segments. Pygidium small and of few segments. Cambrian.

Including the genera and subgenera *Conocoryphe* Corda (= *Conocephalites* Barrande), *Aneucanthus* Angelin, *Atops* Emmons, *Avalonia* Walcott, *Bailiella* Matthew (= *Salteria* Walcott and *Erinnys* Salter), *Bathynotus* Hall, *Carausia* Hicks, *Carmon* Barrande, *Otenocephalus* Corda, *Dictyocephalites* Bergeron, *Eryx* Angelin, *Harttia* Walcott, and *Toxotis* Wallerius.

The genera coming under this family present a number of very primitive characters such as are shown only in the larval stages of higher forms. The free cheeks are narrow and marginal, and can be compared with those in the nepionic stages of *Sao* and *Ptychoparia*. The eyes have not been detected, but the presence of an eye line suggests their possible existence. The variations of the glabella are very marked, and are as great as those which in higher forms attain some importance as family characteristics. In *Toxotis*, *Carausia*, and *Aneucanthus*, the glabella expands in front, joining and forming part of the anterior margin, as in the glabella of the larval stages of *Solen-*

opleura, *Liostracus*, *Ptychoparia*, and *Sao*. *Ctenocephalus* and *Eryx* are slightly more advanced, as the glabella no longer marks the edge of the cephalon. In *Atops*,* *Avalonia*, *Bathynotus*, and *Carmon*, the glabella is cylindrical, distinctly defined, and limited within the margin, and in *Conocoryphe*, *Harttia*, and *Bailiella*, it narrows anteriorly, and only extends about two-thirds the length of the head. Generally in this family, the glabella displays its primitive pentamerous origin. In *Bailiella* and *Carausia*, two basal lobes are marked off from the fourth segment by oblique furrows, as in *Proetus* and *Cyphaspis*.

From a phylogenetic standpoint, the family Conocoryphidæ is at the base of this extensive order. As far as known, all the larval forms in the other families of the Opisthoparia agree in having the narrow marginal free cheeks, bearing the genal angles. The eye line is present in most of the adult Olenidæ, and in the early stages of all as far as known, so that the general average of the characters in the Conocoryphidæ represents the main larval features throughout the other families. They show, too, that although primitive in essential structure, differentiation through time has developed secondary features belonging to genera in higher families, as, for example, the basal glabellar lobes in *Bailiella*.

Family V. OLENIDÆ Salter.

Cephalon larger than the pygidium, usually wider than long; genal angles commonly produced into spines. Free cheeks separate. Facial sutures extending forward from the posterior margin of the cephalon along the eye lobes, and either cutting the anterior margin separately or meeting on the median line. Eyes crescentic, reniform, or semicircular, situated at the ends of eye lines in all but highest genera. Trunk long, composed of from eight (?) to twenty-six free segments: rarely capable of rolling up. Pygidium frequently small; margin entire or spinose.

Principally Cambrian, but extending into the Ordovician.

Including the genus *Olenus* Dalman as the type, and the following genera and subgenera, which should doubtless fall into several subfamily or even family groups: *Acerocare* Angelin, *Acrocephalites* Wallerius, *Agraulus* Corda, *Angelina* Salter, *Anomocare* Angelin, *Anopolenus* Salter, *Asaphe-*

* *Atops* (type *A. trilineatus* Emmons) seems to be a valid genus, and differs from *Conocoryphe* (type *C. Sulzeri* Schlottheim) in its glabellar characters, greater number of thoracic segments, and much smaller pygidium with fewer segments.

lina Bergeron, *Bavarilla* Barrande, *Bergeronia* Matthew, *Boeckia* Brögger, *Ceratopyge* Corda, *Chariocephalus* Hall, *Corynexochus* Angelin, *Crepicephalus* Owen, *Otenopyge* Linnarsson, *Cyclognathus* Linnarsson, *Dikelocephalus* Owen (*Centropoleura* Angelin), *Doripyge* Dames, *Ellipsocephalus* Zenker, *Elliptocephala* Emmons, *Euloma* Angelin, *Eurycare* Angelin, *Holmia* Matthew, *Hydrocephalus* Barrande (=young *Paradoxides*), *Leptoplastus* Angelin, *Liostracus* Angelin, *Logunculus* Devine, *Menocephalus* Owen, *Mesonacis* Walcott, *Micmacca* Matthew, *Neseuretus* Hicks, *Olenelloides* Peach, *Olenellus* Hall, *Olenoides* Meek, *Oryctocephalus* Walcott, *Palæopyge* Salter, *Parabolina* Salter, *Parabolinella* Brögger, *Paradoxides* Brongniart, *Peltura* Angelin, *Plutonides* Hicks, *Proceratopyge* Wallerius, *Protagræulus* Matthew, *Protolenus* Matthew, *Protopeltura* Brögger, *Protypus* Walcott, *Pterocephalia* Roemer, *Ptychaspis* Hall, *Ptychoparia* Corda, *Remopleurides* Portlock, *Sao* Barrande, *Schmidtia* Marcou, *Solenopleura* Angelin, *Sphærophthalmus* Angelin, *Telephus* Barrande, *Triarthrella* Hall, *Triarthrus* Green, and *Zacanthoides* Walcott.

A complete study of this extensive family of trilobites would contribute much in the way of generic synonymy, and bring out the characters necessary for family determination and subdivision. This important work must be left for future investigation. So many genera have been described from separate cranidia or even pygidia as to make it impossible to deal with all of them in a systematic manner. The zeal to make the most out of the earliest known faunas has led many investigators to describe and recognize imperfect and poorly preserved material, and to establish genera upon very tenuous characters. Therefore, without a most intimate knowledge of all the forms, any grouping of the majority of the Cambrian genera into families or the limitations of the genera themselves must, as in the present instance, be taken tentatively and as necessarily incomplete.

A number of genera have already been made the types of family divisions, as *Paradoxides*, *Olenellus*, *Remopleurides*, *Ellipsocephalus*, *Ptychoparia*, etc. Some of them may be shown ultimately to possess characters of sufficient weight to be entitled to family distinction. A preliminary grouping of the best known genera may be of some value here, and for the sake of convenience, these divisions may be defined as sub-families. Four groups will be recognized, of which *Paradoxides*, *Oryctocephalus*, *Olenus*, and *Dikelocephalus* are taken as representative genera.

I. *Paradoxinae*. Including *Olenellus*, *Holmia*, *Mesonacis*, *Elliptocephala*, *Schmidtia*, *Olenelloides*, *Paradoxides*, *Zacanthoides*, and *Remopleurides*. Most of the genera are distinguished by their long narrow eyes, often extending more than half the length of the glabella, but more especially by the rudimentary character of the pygidium. In *Olenellus*, the pygidium is a long telson-like spine. In *Holmia*, *Mesonacis*, *Elliptocephala*, and *Schmidtia*, it is reduced to a small plate without distinct segmental divisions. In *Paradoxides*, *Zacanthoides*, and *Remopleurides*, the axis may show from one to five annulations, while the limb may carry two or three pairs of spines or may be entire. In *Olenellus* and *Holmia*, true facial sutures have been denied by some authors, but in their place false sutures are recognized. They are, however, evidently real sutures in a condition of symphysis, which often occurs in *Phacops*, *Proetus*, *Phillipsia*, etc. Otherwise, these genera would violate the first principle of trilobite structure, in not having the compound eyes on the free cheek pieces. *Olenelloides* is a very striking form, but its pygidium is unknown, and the head structure is obscure. The elongate cephalon is a decidedly larval feature, and the genal and interocular (?) spines strongly suggest its immature condition, and point to the possibility of its being the young of *Olenellus* or a related form.

There has been much discussion as to the synonymy and value of most of the names proposed as genera or subgenera in this group. *Paradoxides*, *Remopleurides*, and *Zacanthoides* are about the only ones that have escaped severe criticism in recent years. Taking the type of each of the others, it is found that *Elliptocephala* (1844) was based on the species *E. asaphoides* Emmons, *Olenellus* (1862) on *O. Thompsoni* Hall, *Mesonacis* (1885) on *M. vermontana* Hall sp., *Holmia* (1890) on *H. Kjerulfi* Linnarsson sp., *Schmidtia* (1890) on *S. Mickwitzi* Schmidt sp., and *Olenelloides* (1894) on *O. armatus* Peach. Some of these names are generally recognized as subgenera of *Olenellus* (*Mesonacis*, *Holmia*, *Olenelloides*), while others are considered as synonyms (*Elliptocephala*, *Schmidtia*). The early genera were described from very incomplete material, and therefore lacked sufficient diagnostic characters to clearly define them. At the present time, nearly or quite entire specimens representing the type species are known, and it is possible to compare all the essential features with some degree of accuracy. The main characters offering the greatest variation are (1) the number of thoracic segments and (2) their specialization into groups, (3) the relative development of the third free segment, (4) the number and position of the spine-bearing segments, (5) the form of the pygidium,

(6) the presence or absence of interocular spines, and (7) the form of the cephalon. A simple variation in any one of these would not necessarily imply more than a specific difference, but the genera here mentioned exhibit marked changes in all or nearly all of these characters, and in any family should receive recognition. *Olenellus*, *Mesonacis*, and *Elliptocephala* are more closely related than the other forms, and probably have only a subgeneric value under *Elliptocephala*. In the first form with fourteen thoracic segments, the third is greatly enlarged and the fifteenth is the spiniform, telson-like pygidium. In *Mesonacis* with twenty-six thoracic segments, the third is somewhat enlarged, and behind the narrow spine-bearing fifteenth segment there are eleven others without spines, followed by the small plate-like pygidium. In *Elliptocephala* with eighteen thoracic segments, the cephalon is broader, the third segment is not enlarged except in the young, and the fourteenth to eighteenth segments are narrower and spine-bearing.

II. *Oryctocephalinæ*. Including *Oryctocephalus*, *Otenopyge*, *Olenoides*, and *Parabolina*, with large pygidia and all but the last one or two pleural elements continued into spines; also *Eurycare*, *Angelina*, *Peltura*, and *Protopeltura*, with smaller and shorter pygidia and denticulations of the margins corresponding to the pleural divisions.

III. *Oleninæ*. Including *Olenus*, *Agraulus*, *Liostracus*, *Acerocare*, *Ptychoparia*, *Solenopleura*, *Ptychaspis*, *Leptoplastus*, *Loganellus*, *Sphærophthalmus*, *Parabolinella*, *Boeckia*, *Proceratopyge*, *Ceratopyge*, *Protypus*, *Ellipsocephalus*, *Sao*, and *Triarthrus*. All these genera have small or medium-sized pygidia, with from two to eight annulations in the axis. Eyes medium to small, at the ends of distinct eye lines in all but the latest genera, which preserve this character only during the young stages. Thoracic segments from eleven to eighteen.

IV. *Dikelocephalinæ*. Including *Dikelocephalus*, *Asaphelina*, and *Crepicephalus*. Eight or nine thoracic segments. Pygidium wide, with the posterior lateral portion often produced into broad spine-like extensions. *Dikelocephalus* is in many ways related to *Ogygia* and *Asaphus*.

Family VI. ASAPHIDÆ Emmrich.

Cephalon and pygidium well developed; glabella often obscurely limited. Free cheeks usually separate. Facial sutures extending forward from the posterior edge of the cephalon within the genal angles, and cutting the lateral or anterior margins, occasionally uniting in front of the glabella.

Eyes smooth, well developed, sometimes of very large size, even occupying the entire surface of the free cheeks. Thorax generally composed of eight or ten segments, but varying from five to ten; capable of enrollment. Pygidium large, often with wide doublure.

Cambrian, Ordovician, and Silurian.

The long list of genera in this family may easily be divided into two sections, which are often recognized as of family rank.

I. ASAPHIDÆ. Including the genera and subgenera *Asaphus* Brongniart (= *Cryptonymus* Eichwald), *Asaphellus* Callaway, *Asaphiscus* Meek, *Barrandia* McCoy, *Basiliscus* Salter, *Bathyurellus* Billings, *Bathyriscus* Meek, *Bathyrurus* Billings, *Bolbocephalus* Whitfield, *Brachyaspis* Salter, *Bronteopsis* W. Thompson, *Dolichometopus* Angelin, *Gerasaphes* Clarke, *Holasaphus* Matthew, *Homalopecten* Salter, *Isotelus* DeKay, *Megalaspides* Brögger, *Megalaspis* Angelin, *Niobe* Angelin, *Ogygia* Brongniart, *Ogygiopsis* Walcott, *Phillipsinella* Novák, *Platypeltis* Callaway, *Ptychopyge* Angelin, and *Stygina* Salter.

This is a tolerably homogeneous group, although some of the Cambrian forms have a sufficiently archaic expression to make them seem a little out of place with genera of so pronounced a family type as *Asaphus*, *Niobe*, *Ptychopyge*, *Megalaspis*, and *Isotelus*.

The elements of the glabella are generally quite obscure, and even its limits cannot be clearly made out in late genera, as *Stygina* and *Asaphus*. The segmental nature of the glabella is clearly shown in *Ogygia*, *Ogygiopsis*, *Homalopecten*, *Asaphellus*, *Bronteopsis*, and *Bathyriscus*.

The elements of the pygidium are obscurely marked in *Brachyaspis* and *Isotelus*. *Phillipsinella* is a very small form, and probably the young of an *Asaphus*. *Barrandia*, *Homalopecten*, and *Stygina* serve as transition genera to the Illænidæ.

II. ILLÆNIDÆ. Including the genera and subgenera *Illænus* Dalman, *Æglina* Barrande (= *Cyclopyge* Corda), *Bumastus* Murchison, *Dysplanus* Burmeister, *Ectillænus* Salter, *Holocephalina* Salter, *Hydrolenus* Salter, *Illænoopsis* Salter, *Illænurus* Hall, *Nileus* Dalman, *Octillænus* Salter, *Panderia* Volborth, *Psilocephalus* Salter, *Symphysurus* Goldfuss, and *Thaleops* Conrad.

The Illænidæ form a much more compact group than the preceding, characterized by having an epistomal plate and by

the very tumid form of the large cephalon and the obscure or obsolete boundaries of the glabella and occipital lobe. The pygidium often closely resembles the cephalon in size and form, and the axis is frequently scarcely defined.

Considerable variation is shown in the size, position, and direction of the visual surfaces. There is also a ratio between the size of the fixed cheeks and the eyes. In proportion as the fixed cheeks are large, the eyes are small, and as the area of the fixed cheeks diminishes from a widening of the axis of the animal, the eyes become larger. Thus, in *Holocephalina*, with extremely large fixed cheeks and narrow axis, the eyes are quite small. In *Illænopsis*, *Dysplanus*, *Panderia*, and *Octillænus*, they are progressively larger, and in *Illænus*, *Bumastus*, and *Nileus*, where the axis is wide and the fixed cheeks reduced, the eyes are relatively large. This variation reaches its limit in the species of *Æglina*, where the axis is very wide and the fixed cheeks are reduced to almost nothing, so that the glabella and eyes make up the entire dorsal surface of the cephalon. In *Æglina princeps* Barrande, the eyes extend about half the length of the cephalon. The eyes of *Æ. rediviva* Barr. bound the whole length of the sides of the head, and in *Æ. armata* Barr., the coalesced free cheek pieces are almost wholly converted into a visual area, so that there is a continuous eye around the sides and front of the head.

Variations in the position of the eyes are to be noted in nearly all the genera. In *Ectillænus* and *Psilocephalus*, they are in front of the middle of the length of the cephalon, and in *Dysplanus*, *Illænopsis*, and *Holocephalina*, they are near the posterior angles of the cranidium. *Panderia* has the eyes directed obliquely backward, and in *Thaleops*, they are carried on conical extensions pointing outwards.

Family VII. PROËTIDÆ Barrande.

Cephalon about one-third of the whole animal; genal angles generally produced into spines; glabella tumid, with two lateral basal lobes defined by oblique furrows in front of the neck segment. Free cheeks large, separate. Sutures extending from the posterior margin inward to the eyes, and then forward, cutting the anterior margins separately. Eyes prominent, often large. Thorax of from eight to twenty-two free segments, with grooved pleura. Pygidium usually of many segments; pleural and axial portions strongly grooved; margin entire or dentate.

Ordovician to Permian.

Including the genera and subgenera *Proëtus* Steininger,

Arethusina Barrande, *Brachymetopus* McCoy, *Celmus* Angelin, *Cordania* Clarke, *Crotalurus* Volborth, *Cyphaspis* Burmeister, *Dechenella* Kayser, *Griffithides* Portlock, *Phaëtونها* Novák, *Phillipsia* Portlock, *Prionopeltis* Corda, *Pseudophillipsia* Gemmellaro, *Schmidtella* Tschernyschew, *Tropidocoryphe* Novák, and *Xiphogomium* Corda.

The genera of this family readily fall into a series expressing more or less closely the development and specialization of various characters. *Arethusina* is the only genus retaining the archaic eye lines, and both on this account and for the comparatively forward position of the eyes (itself a nepionic character), together with the large number of thoracic segments, it stands near the base of the series.

The eyes gradually approach the axis, and move backward through the genera *Tropidocoryphe*, *Cyphaspis*, *Proëtus*, *Prionopeltis*, *Phillipsia*, and *Griffithides*. Concurrent with this variation, there is a reduction of the fixed cheeks and extension of the glabella. In *Arethusina*, *Tropidocoryphe*, *Cordania*, and *Cyphaspis*, the fixed cheeks are about the size of the free cheeks, and occupy a large portion of the cranidium. They are more reduced in *Proëtus* and *Prionopeltis*, and in *Phillipsia* and *Griffithides*, they form only a narrow border to the glabella. The lobation of the glabella varies greatly, and few species retain evidences of its original segmental nature. Some *Proëtus* and *Dechenella* show this feature, but in many *Phillipsia* and *Griffithides* the elements cannot be made out. In *Proëtus*, there is often a small accessory lobe developed at the ends of the neck ring, which is only of interest as being homologous with similar lobes in many of the Lichadidæ and Acidaspidæ, where they often become very conspicuous. In all the Proëtidæ, the oblique lobes of the fourth annulus of the glabella are also important in this connection, as here again is marked the inception of side axial lobes, which become prominent features in higher genera, indicating greater specialization of the organs and appendages of the head.

Family VIII. BRONTEIDÆ Barrande.

Dorsal shield broadly elliptical. Cephalon less than one-third the entire length; glabella rapidly expanding in front, with faint indications of lobes. Free cheeks larger than the fixed cheeks. Facial sutures extending from the posterior margin just behind the eyes abruptly inward around the palpebral

lobes, and then diverging and cutting the antero-lateral margins separately. Eyes crescentic. Thorax of ten segments, with ridged pleura. Pygidium longer than cephalon or thorax; axis very short, with radiating furrows extending from it across the broad limb toward the margin; doublure very wide; margin generally entire. Ordovician to Devonian.

Including the single genus *Bronteus* Goldfuss (= *Goldius* de Koninck).

Many of the species of *Bronteus* (as *B. angusticeps* Barr., *B. palifer* Bey.) show a breaking up of the glabella into symmetrically disposed separate lobes, as in *Conolichas* and *Acidaspis*. The frontal lobe is transverse and much larger than the others. Back of it may be simple grooves marking the elements (*B. campanifer* Bey.), or there may be one or two circular or elliptical swellings on each side of the axis (*B. angusticeps* Barr.), or in addition, the axial portion may consist of several lobes. The reduction of the axis of the pygidium and the expansion of the limb meet with their greatest expression in this genus. *Lichas* shows the decline of these characters, the pygidial limb becoming more or less deeply lobed, and finally the lobes are represented by spines (*Arges*, *Terataspis*). Further progression of these changes is shown in *Acidaspis*.

Family IX. LICHADIDÆ Barrande.

Dorsal shield generally large and flat, with granulated test. Cephalon small, not more than one-fourth the entire length; genal angles spiniform. Free cheeks separate; sutures extending from the posterior margin obliquely inward to the eyes, and then almost directly forward, cutting the margin separately. Glabella broad, with a large, often tumid, central lobe and from one to three side lobes. Eyes not large. Thorax with nine or ten segments and grooved and falcate pleura. Pygidium large, flat, commonly with toothed or notched margin corresponding to the pleural grooves; doublure very broad.

Ordovician to Devonian.

Including the genera and subgenera *Lichas* Dalman, *Arctinurus* Castelnau, *Arges* Goldfuss, *Ceratolichas* Hall and Clarke, *Conolichas* Dames, *Dicranognmus* Corda, *Homolichas* Schmidt, *Hoplolichas* Dames, *Leiolichas* Schmidt, *Metopias* Eichwald, *Oncholichas* Schmidt, *Platymetopus* Angelin, *Terataspis* Hall, *Trochurus* Beyrich, and *Uralichas* Delgado.

Most of the forms of this family are above the average size of trilobites, and several species are among the largest of the class. They are all thin-shelled, and were loosely articulated, so that entire specimens are extremely rare.

A great diversity is shown in the form and lobation of the glabella. In *Lichas* (sens. str.), *Platymetopus*, and *Leiolichas*, the anterior lobe dominates and is continuous with the axis. In *Hoplolichas* and *Homolichas*, the lateral lobes are strongly defined, and each is nearly equal in size to the central lobe. *Dicranognmus*, *Oncholichas*, *Conolichas*, *Metopias*, *Arctinurus*, and *Arges* show the lateral lobes divided transversely into two or three smaller ones. Lastly in *Ceratolichas*, and more especially in *Terataspis*, the central lobe becomes a prominent ovoid or globular extension. These variations evidently indicate differences in the relative development of the appendages and organs of the head, and therefore are of considerable morphological importance.

The pygidium is composed of few distinct segments. The annulated portion of the axis is generally short, and the dentations on the border of the limb, corresponding to the pleural grooves, range from two to four on each side. *Leiolichas* is the only form which has an entire pygidial margin.

Family X. ACIDASPIDÆ Barrande.

Dorsal shield spinose. Cephalon transversely semi-elliptical, quadrate, or trapezoidal; genal angles spiniform. Glabella with one large median axial lobe and two or three lateral lobes. Free cheeks large, separate. Sutures extending from within the genal angles abruptly inward to the eyes, and then forward, cutting the anterior margin each side of the glabella. Eyes small, often prominent. Thorax of eight to ten segments, with ridged pleura extended into hollow spines. Pygidium usually small, with spinous margin. Ordovician to Devonian.

Including the genera and subgenera *Acidaspis* Murchison, *Ancyropyge* Clarke, *Ceratocephala* Warder, *Dicranurus* Conrad, *Odontopleura* Emmrich, and *Selenopeltis* Corda.

In this family and the Lichadidæ is shown the highest expression of differentiation and specialization of the Opisthoparia. The primitive pentamerous lobation of the axis of the cranidium is entirely obscured, and is only clearly seen in the protaspis and early nepionic stages. These two families are very closely related, the chief differences being noticed in the size and character of the pygidium, and the ribbed or grooved

pleura. The Lichades are generally much larger and flatter, but the smaller and highly spinose forms of *Arges*, *Ceratolichas*, and *Hoplolichas* approach quite near some of the *Acidaspidæ*.

It has been customary of late years to regard all the species of this family as belonging to the single genus *Acidaspis*, and to consider the various subdivisions bearing separate names as of the value of subgenera. Clarke¹⁴ has shown that, on the basis of priority, *Ceratocephala* is the first distinctive name ever applied to the group, and is therefore entitled to full generic recognition. He further recognizes *Odontopleura*, *Acidaspis*, *Dicranurus*, *Selenopeltis*, and *Ancyropyge*, in the subordinate position of subgenera under *Ceratocephala*.

Order C. PROPARIA, n. ord.

(*πρό* before, and *πᾶρειά* cheek piece.)

Free cheeks not bearing the genal angles. Facial sutures extending from the lateral margins of the cephalon in front of the genal angles, inward and forward, cutting the anterior margin separately or uniting in front of the glabella. Compound paired eyes scarcely developed or sometimes absent in the most primitive family, well-developed and schizochroal in last family.

Including the families Encrinuridæ, Calymenidæ, Cheiruridæ, and Phacopidæ.

Salter's first division, *Phacopini*, included the two families Phacopidæ and Cheiruridæ. The Calymenidæ were placed in his second division, the *Asaphini*.

This is the only order of trilobites which apparently begins within the known Paleozoic, and unlike the other orders, it had no pre-Cambrian existence. The earliest forms of the Proparia came at the close of the Cambrian, in the lower Ordovician. Its greatest generic differentiation was attained early. There is a rapid decline in the Silurian and Devonian, and only one or two genera extend to the beginning of the Carboniferous.

In the Opisthoparia, it was demonstrated that the Conocoryphidæ formed the natural base or most primitive family in the order, and was distinguished by the narrow marginal free cheeks and the absence of well-developed eyes. It is of much interest and importance to be able to recognize, in the Proparia, a similar primitive family having characters in common with the former, but still clearly belonging to the higher order. *Placoparia*, *Areia*, and *Dindymene*, of the Encrinuridæ, constitute a group of apparently blind trilobites, with narrow mar-

ginal free cheeks, presenting in general the appearance of *Atops*, *Conocoryphe*, *Otenocephalus*, etc., of the Conocoryphidæ. The somewhat higher genera *Cybele* and *Encrinurus* have intermediate or transitional characters, leading to the other families. The Cheiruridæ show a greater amount of differentiation and progressive and regressive evolution than any other in this order. *Crotalocephalus* and *Sphærexochus* seem to express the highest development, and *Deiphon* and *Onycopyge* show the effects of over specialization, resulting in degeneration. The Calymenidæ, in their small eyes and narrow free cheeks, have decided affinities with the lower genera. The same may be said of *Trimericephalus* of the Phacopidæ, though the other genera of this family possess large eyes, situated well back and close to the glabella. For these and other reasons, the family is placed at the end of the order, as expressing its highest development.

Family XI. ENCRINURIDÆ Linnarsson.

Cephalon narrow, transverse. Fixed cheeks very large. Free cheeks long, narrow, separate, sometimes with a free plate between the anterior extremities. Sutures extending from in front of the genal angles obliquely forward, and cutting the anterior margin in front of the glabella. Eyes very small or absent. Thorax of from nine to twelve segments, with ridged pleura. Pygidium generally composed of many segments; limb with strong ribs usually less in number than the annulations of the axis. Ordovician and Silurian.

Including the genera *Encrinurus* Emmrich (*Cromus* Barande), *Areia* Barande, *Cybele* Lovén, *Dindymene* Corda, *Placoparia* Corda, and *Prosopiscus* Salter.

The Conocoryphidæ were shown to be the radical of the order Opisthoparia, and for similar reasons, the Encrinuridæ may now be taken as the primitive family of the Proparia. The cephalæ of *Areia* and *Placoparia* have many resemblances to *Conocoryphe*, but the fixed cheeks bear the genal angles and spines, while in the latter genus they are on the free cheeks. In both families, the free cheeks are narrow and marginal, and the eyes are absent or rudimentary. Both these characters are decidedly larval. Other primitive and larval features belonging to the Encrinuridæ are the eye lines in *Cybele* and *Encrinurus*, the undefined and expanded termination of the glabella in *Dindymene* and *Encrinurus*, and the pentamerous head axis in all but *Dindymene*, in which the four anterior lobes or

annulations are obsolete. In *Encrinurus*, the eye line in meeting and joining the anterior lobe of the glabella sometimes gives the appearance of an extra lobe, as in *Ogygia* and *Paradoxides*.

Family XII. CALYMENIDÆ Brongniart.

Cephalon somewhat wider than long. Fixed cheeks large; genal angles rounded or produced into spines. Glabella narrowing anteriorly. Free cheeks long, separate, usually with a free plate, the epistoma, between the anterior extremities. Sutures extending from just in front of the genal angles, converging anteriorly, and cutting the margins separately. Eyes small; visual surface seldom preserved. Thorax of thirteen segments, with grooved pleura. Pygidium of from six to fourteen segments; axis tapering. Ordovician to Devonian.

Including the genera and subgenera *Calymene* Brongniart, *Brongniartia* Salter, *Burmeisteria* Salter, *Calymenella* Bergeron, *Calymenopsis* Munier-Chalmas and Bergeron, *Dipleura* Green, *Homalonotus* Koenig, *Koenigia* (= *Homalonotus*) Salter, *Pharostoma* Corda, *Plasiacomia* Corda, *Ptychometopus* Schmidt, and *Trimerus* Green.

The genera of this family naturally cluster around the two leading ones, *Calymene* and *Homalonotus*. Closely related to the first are *Ptychometopus*, *Pharostoma*, *Calymenopsis*, and *Calymenella*, all agreeing in having the glabella well defined and marked by furrows or indentations at the sides, corresponding to its segmental nature.

The second group, including *Brongniartia*, *Trimerus*, *Homalonotus* (sens. str.), *Plasiacomia*, *Dipleura*, and *Burmeisteria*, agree in having a low, not sharply defined, quadrate glabella, without distinct furrows or lobes. In general, the axis of the thorax and pygidium is much wider than in the first group, and the pygidium is more elongate and often pointed.

Family XIII. CHEIRURIDÆ Salter.

Glabella well defined. Free cheeks small, sometimes much reduced. Sutures extending from in front of the genal angles inward to the eyes, and then obliquely forward, cutting the anterior margin in front and each side of the glabella. Eyes usually small. Thorax composed of from nine to eighteen segments, generally eleven; pleura often extended into hollow spines. Pygidium small, with from three to five segments; pleural elements commonly produced into spines.

Principally Ordovician and Silurian, but extending into the Devonian.

Including the genera and subgenera *Cheirurus* Beyrich, *Actinopeltis* Corda, *Amphion* Pander, *Anacheirurus* Reed, *Ceraurus* Green, *Crotalocephalus* Salter, *Cyrtometopus* Angelin, *Deiphon* Barrande, *Diaphanometopus* Schmidt, *Eccoptocheile* Corda, *Hemisphærocoryphe* Reed, *Nieszkowskia* Schmidt, *Onycopye* Woodward, *Pseudosphærexochus* Schmidt, *Sphærexochus* Beyrich, *Sphærocoryphe* Angelin, *Staurocephalus* Barrande, and *Youngia* Lindström.

As in other families, the most primitive genera are those in which the regular pentamerous lobation of the glabella is retained, the eyes are well forward, the free cheeks narrow, and the fixed cheeks ample. *Diaphanometopus*, *Anacheirurus*, *Eccoptocheile*, and *Cyrtometopus* agree in these respects, and therefore belong at the beginning of a phylogenetic list. *Ceraurus* and *Nieszkowskia* appear to branch off here, being characterized by the narrow transverse form of the cephalon and the great development of the two anterior pygidial pleura into hollow spines directed outward and backward. These features are simulated in *Deiphon*, in which, however, the prominent glabella is without distinct lobes, and the large pleural extensions of the pygidium do not belong to the anterior segment. Its natural place is at the end of the series. F. Cowper Reed³¹ has shown, in his memoir on the evolution of *Cheirurus* and its subgenera, not including the other genera of the family, that the direct line from *Cyrtometopus* passes through *Cheirurus* to *Crotalocephalus*. The genera *Pseudosphærexochus* and *Amphion* also have relations with these genera and should be placed here. There is next a group of forms, with prominent globular glabellæ, leading from *Cheirurus* to *Sphærocoryphe*, and including *Actinopeltis*, *Youngia*, and *Hemisphærocoryphe*. *Staurocephalus* should immediately follow these. *Sphærexochus* seems to be related to *Cheirurus* and *Actinopeltis*. Like them, it has two side lobes at the base of the glabella, and the anterior furrows are obsolescent, as in *Actinopeltis* and *Youngia*. Lastly come *Onycopye* and *Deiphon*, with their globular glabellæ without furrows, the spiniform fixed cheeks, and thoracic and pygidial pleura, and the free cheeks reduced to almost nothing, forming a small part of the doublure of the cephalon. The former genus has four spiniform pygidial pleura, two on each side, but in the latter, two are reduced and the remaining pair is greatly enlarged.

Family XIV. PHACOPIDÆ Salter.

Glabella tumid, widest in front. Free cheeks continuous, united anteriorly. Suture extending from in front of the genal angles inward to the eyes, and then forward around the glabella. Eyes generally large, and always with distinct facets, schizochroal. Thorax with eleven segments, with grooved pleura. Pygidium usually large and of many segments; limb ribbed; margin entire or dentate. Ordovician to Devonian.

Including the genera and subgenera *Phacops* Emmrich, *Acaste* Goldfuss, *Chasmops* McCoy, *Coronura* Hall, *Corycephalus* Hall and Clarke, *Cryphæus* Green, *Dalmanites* Emmrich (*Hausmannia* Hall and Clarke), *Homalops* Remele and Dames, *Monorachos* Schmidt, *Odontocephalus* Conrad, *Pterygometopus* Schmidt, *Symphoria* Clarke, and *Trimerocephalus* McCoy.

The last family of trilobites comprises forms which are commonly believed to be the most highly organized of the class, and certain it is that a high degree of organization is manifested. Some of the characters may be considered as progressive, while others are larval or possessed chiefly by the most primitive families, and are therefore to be looked upon as regressive. Schizochroal eyes occur in no other family, and this feature is apparently indeterminate. The complete union of the free cheeks, carrying the doublure of the sides and front of the cephalon, can be best homologized with similar structures in some of the lowest genera, and is a retention of the complete ocular segment. The glabella, though considerably enlarged anteriorly, does not attain the degree of specialization shown in *Lichas* and *Acidaspis*. Only *Chasmops* and related forms (*Monorachos*, *Homalops*, *Symphoria*, and *Coronura*) have separate or accessory lobes. The margin of the cephalon shows even greater diversity than in any other family. It may be plain (*Phacops*, *Cryphæus*), notched (*Corycephalus*), denticulated (*Odontocephalus*), or extended in front as a spinose, spatulate, or dentate process (*Dalmanites nasutus* Conrad, *D. tridens* Hall, etc.). The pygidium has a range almost as great, though in this respect it is equalled in the *Lichadidæ*, *Acidaspidæ*, and some of the *Olenidæ*. In America, the section typified by *Dalmanites* culminated during the lower Devonian. Not only are the largest forms found here (*Coronura diurus* Green, *C. myrmecophorus* Green, *D. tridens* Hall, etc.), but also the most ornate and specialized, as *Corycephalus*, *Odontocephalus*, and *Coronura*.

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EXPLANATION OF PLATE III.

Figures are approximately of the same size to facilitate comparison. The dorsal areas of the free cheeks are shaded.

Ontogeny of Sao hirsuta Barrande.

- FIGURE 1.—Protaspis stage.
 FIGURE 2.—Cephalon; nepionic stage of individual having two free thoracic segments.
 FIGURE 3.—Cephalon; later nepionic stage of individual having eight free thoracic segments.
 FIGURE 4.—Cephalon of adult. Figures 1-4, after Barrande.

Ontogeny of Dalmanites socialis Barrande.

- FIGURE 5.—Protaspis stage.
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 FIGURE 8.—Cephalon of adult. Figures 5-8, after Barrande.

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| FIGURE 10.—Cephalon of <i>Microdiscus</i> . | |
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ERRATA.

Page 92, line 19, for *Zecanthoides* read *Zacanthoides*.

Page 95, line 24, for enervate read innervate.

Page 95, line 25, for enervated read innervated.

Page 96, lines 31 and 34, for enervating read innervating.

Page 103, line 18, for *Olenellus* read *Elliptocephala*.

ART. XIX.—*The Scoured Boulders of the Mattawa Valley*;
by F. B. TAYLOR.

INTRODUCTION.

THE author spent the last week in September and the first half of October just passed in exploring the valley of the Mattawa river in the Province of Ontario. The chief object of search was to discover whether there is any clear evidence of the recent flow of a great river eastward along this course to the Ottawa valley. For this is the site of a supposed former outlet of the upper Great Lakes. It has been supposed, first by Mr. G. K. Gilbert, and later by Prof. G. F. Wright and the author, that there was a period since the disappearance of the ice-sheet during which Lakes Superior, Michigan, and Huron discharged their waters eastward to the Ottawa valley along the present course of the Mattawa river. During this period Lake Erie alone retained its outlet through Niagara river to the basin of Lake Ontario. It does not fall within the intended scope of this paper to discuss all the facts relating to the existence of the Nipissing-Mattawa river, as the ancient outlet river may be called, nor to discuss exhaustively the facts relating to its duration and date. It will suffice here to state that from several kinds of evidence the existence of the great outlet river is believed to be established beyond a doubt; and further, that it endured for a comparatively long period of time and ceased to exist probably considerably less than ten thousand years ago. Hence, while it is geologically a very recent thing, it may very properly be spoken of in a historical sense as ancient.

No more conclusive evidence of the existence of the ancient river could be expected than that which has been gathered this season from a study of the numerous boulders that lay in its rapids. The volume of the river, it is fair to assume, was practically the same as that of the St. Clair river to-day, and was equally steady in its flow. In rapids of moderate velocity, where the river flowed over a sill closely paved with large boulders, the action of the current rolling small quantities of gravel over, around and between the boulders produced certain wearing or scouring effects which are very characteristic. The forms so produced are not known to be made in any other way. It is the object of this paper to present a brief account of these peculiar boulders as they appear to-day in the valley of the Mattawa, many of them as much as forty feet above the present river. A few remarks will also be added about the conditions and the processes of their production.

The bowlders which show these modifications are almost all large, ranging from about two to twenty-five or thirty feet in diameter. Bowlders of large size are extremely numerous on the areas where these forms are found, completely covering over the surface of the ground. They are all of very hard crystalline rock; some are red or gray granite, and some are greenstones, but by far the greater number are of the hard foliated gneiss which is so common in the surrounding region. Many of the large bowlders of gneiss, even after the long exposure to weather which they have undergone, show no signs of fracture or breaking. So far as observed the bowldery areas of the former rapids of the river appear to be associated with belts of morainic accumulation.

Varieties.

One may best learn the processes by which scoured bowlders are made by studying the action of the current in bowldery rapids of the modern river at a time of low water. In passing over and among the bowlders the current is very much disturbed. It is turned aside suddenly and thrown this way and that; it strikes against the front or the sides of some bowlders and passes through narrow passages between others; it glides smoothly over the tops of some and falls heavily on the tops of others, and in a few cases it is thrown into a vortex whirl in an angle or slight depression on the surface of a bowlder. Just as the billows in a rocky rapid remain constant in position, so these various turns and whirls in the current beneath the surface remain constant in place and action so long as the bowlders lie unmoved. Thus the currents that play upon a bowlder are generally constant in the particular manner of their action. Where sand and small pebbles are being borne along in small or moderate quantities, they follow the deviations of the current from bowlder to bowlder, and each sand-grain and pebble does a little work of abrasion as it goes along. Every one that follows the same course among the bowlders performs its iota of work upon the same part, so that the wear on each bowlder comes where the current impinges upon it. In the course of time, but very slowly, the bowlders are worn into the fantastic shapes which are here called scoured bowlders. The forms which the bowlders take under the scour of the sand- and pebble-bearing current are quite varied. But after examining several hundreds of specimens it became apparent that all could be classified according to their forms under a few heads, although a few individual cases would have to stand as intermediate forms. Six varieties may be distinguished as follows:

Scoured Boulders.

1. Pierced (Ring-boulders).
2. Basined.
3. Nighed.
4. Guttered.
5. Facetted.
6. Smoothed.

The table of varieties of form as given above is offered only provisionally. For it is quite probable that a more extended study of the subject would suggest some modifications. In forming the table, however, the writer has had the advantage of discussion and joint observation with Dr. Robert Bell, Assistant Director of the Geological Survey of Canada. Shortly after the beginning of the study of the boulders at Mattawa, Dr. Bell arrived from James Bay and during three or four days delay from other causes, gave a part of his time to the study of the scoured boulders. The names of some of the varieties as presented in the table were suggested by him. These names are based mainly on forms of scoured boulders found on the terraces at Mattawa and in the modern rapids of the Mattawa and Ottawa rivers. The observations of this season, however, are not the only ones that the writer has made. Basined boulders were observed in 1895 in the rapids of the Ottawa both above and below Mattawa and also in the rapids of the Nipigon. Some of the less pronounced forms were found in 1894 in several of the streams that course down the slopes of the Alps, in the Maggia especially, and to some extent also in the Toce and Ticino. In 1893 a few basined boulders were seen in the Au Sable and Saranac rivers in the Adirondacks. The first boulders of this kind noted by the writer were seen in 1888 and 1889 in some of the rapids of Grand river above Hot Sulphur Springs in Middle Park, Colorado, and they were also seen in several other rivers in the same state. Some of those in Grand river show well-developed potholes.

Distribution.

Scoured boulders of the more pronounced types may be produced in almost any stream of large or moderate size provided certain conditions of stability obtain. The boulders must be permanent in position for a long period, and the general direction of the current must not change. There must also be a fairly constant supply of sand and gravel, moderate in amount, for the current to roll along as it moves over the boulders. Streams meandering in alluvial plains are not likely to show effects of this kind. Even streams flowing in drift beds suffer so many alterations of their courses, due to caving banks and

deepening beds, that they produce generally only the smoothed variety, which does not require constancy of position. Nearly all streams produce this simplest form. Scour effects on bowlders are sometimes found even in small streams, where their courses are permanently choked with great bowlders through which the stream trickles constantly. But so far as known to the writer, the Mattawa valley is the first case where the existence of a great ancient river now extinct has been inferred from such evidence.

Besides the scoured bowlders on the terrace at Mattawa there is but one other place higher up the Mattawa valley where these peculiar stones were made in large numbers in rapids of the ancient river. At Des Epines rapids, eight and one-quarter miles above Mattawa, scoured bowlders are developed in great profusion and perfection of form at heights entirely above the reach of the modern river. At this place bowlders with deep basins or potholes in them were found on the north side over forty feet above the water.

On a comparison of the results of observations on the several bowldery rapids of the ancient river, a very clear explanation of the plentiful occurrence of scoured bowlders in some rapids and their scarcity or absence in others was found. Wherever a stream of sufficient volume to transport gravel in considerable quantities descended from the adjacent high drift-covered country and poured its contribution into the ancient outlet at or just above a rapid, scoured bowlders are numerous. But where the water that passed over the bowlders issued directly from a lake, and hence without any such supply of gravel, scoured bowlders are few or absent altogether. Boom creek entered the ancient outlet on the south side about a mile above Mattawa and furnished an abundant supply of gravel for the current to roll along over the bowlders of the Mattawa terrace. That Boom creek did in fact supply a large amount of gravel is attested by the present existence of a very considerable delta of sand and gravel 50 to 60 feet above the modern Mattawa river where the creek enters the old channel. The influence of the ancient outlet current is shown by the fact that these sediments have been carried down that side of the channel quite extensively and spread over part of the bowldery terrace. At Des Epines rapids the gravel supply came from the Amable du Fond river, which enters on the south side less than half a mile above. This stream is nearly as large as the Mattawa itself and it cuts extensive gravel beds a short distance above its mouth.

On the other hand, in the bowldery rapids at the head of Lost river (foot of Turtle lake) no basined bowlders and few even of the less pronounced forms of scour were found. They

appeared to be absent also in the ancient bowldery rapids next below Pimisi bay and at the Rapide des Rochers below Lac des Aiguilles. At all these places the current issued directly from a lake and was probably clear and free of gravelly sediments.

So far as seen the best place to observe bowlders being scoured by the work of the modern Mattawa river is at the Chute des Parasseux, fourteen miles above Mattawa.

Descriptive Details of Varieties.

Pierced and basined bowlders are in reality merely two stages of the same process. When the current begins to cause pebbles and sand to spin round and round on one particular spot on the surface of a bowlder, the process of wearing out a basin is begun. Given only time enough, with constancy of the conditions on which the whirl depends, and the basin will sink deeper and deeper into the solid bowlder until the bottom is cut through and the basin becomes a hole. The bowlder is then pierced through and becomes a ring-bowlder. The hole is usually nearly circular on cross section, but sometimes tapers towards the bottom. The periphery or outer surface of the stone generally shows considerable irregularity, for the hole is seldom symmetrically placed. Otherwise these bowlders have the common sub-angular form. Pierced or ring-bowlders are the highest type or variety of the several forms produced by scour. They are scarce, even where other lower varieties are abundant. Only one was found on the course of the ancient outlet river within the Mattawa valley, and this lies in such a position and at so low a level with reference to the modern river that it probably was made by it. This ring-bowlder lies in a side channel at Parasseux Chute. A dam was constructed across the head of the rapids several years ago and this left a side channel east of the present rapids dry. In the bottom of this channel about opposite the middle of the present rapids below the dam lies the ring-bowlder. It is broken in two pieces, but they are separated only a few inches and their former solidity as an unbroken ring is at once obvious. The hole is not perfectly circular, but has a large diameter compared with the diameter of the bowlder itself. The hole is about eighteen inches across, while for about one-third of the circumference the ring of rock is only six or seven inches thick.

But the most magnificent specimen of this variety that the writer has seen is on the bank of the Ottawa river near Klock's, ten miles below Mattawa. This bowlder is large—about seven feet long, five wide and four thick. The hole is

about eighteen or twenty inches across at the top, but tapers to about eight or ten inches at the bottom. The boulder has evidently been slightly tilted since it was bored out, and may, indeed, have been moved a considerable distance. It lies at the edge of the water a few rods up stream from the residence of the Hon. James B. Klock, and is readily visible only at low water.

From the Rev. E. Macnab of Mattawa the writer learned of another ring-boulder which may be seen on the bank of Lake Temiscamang at the narrows at old Fort Temiscamang near Baie des Pères. In this case a tree grew up through the aperture and finally broke the boulder in two. The stone was literally strung on the tree.

Basined boulders are much more numerous. They are fairly abundant in the rapids of the ancient outlet at Des Epines rapids and at Mattawa and also in several of those of the modern Mattawa and Ottawa. They exist in all stages of development ranging from a saucer-like depression barely deep enough to hold a spoonful of water to well-developed potholes a foot or more in depth. Occasionally one is found which is very irregular in shape—a peculiarity which is generally due to some unevenness in the composition of the rock. Several boulders were found in which a well-developed basin had a deep cut in the rim or on one side. This appeared to be due to the wearing through of a thin side wall. A good specimen of this modified form lies on the edge of the railroad cut about forty feet south of the overhead bridge opposite O'Farrell's hotel in Mattawa. This one is about 35 or 40 feet above low water in the Mattawa. Many basined boulders were found at heights from fifteen or twenty up to about forty feet on ground east and southeast of the hotel. On the north bank at Des Epines rapids three good specimens were found forty feet above the modern Mattawa and several others were found at lower levels.

Niched boulders that can be surely distinguished from other forms are hardly so common as the basined variety. The niche is a shallow hollow worn into the side of the boulder, in form somewhat resembling a wall-niche for statues or statuettes. A number of examples were found at Mattawa concerning which there can be no doubt. For the boulder had evidently received its marks of scour *in situ*. This was the case with the great boulders especially. In the case of many small boulders, however, the worn cavities may have had a different origin. If a small boulder had a small shallow basin worn on its top and then had been turned over on its side, the basin would then have the appearance of a true niche. No doubt many have had this origin. But in several instances it was plain that the niche had been worn while the boulder was in exactly the same position as to-day.

Shallow, smooth-worn hollows are often found on the slanting sides of boulders, and sometimes on stones no larger than a foot in diameter. The origin of such forms can seldom be made out with certainty unless it is clear that the stone has remained unmoved. In a few cases two boulders lying close together had complementary grooves or hollows in them. Probably nearly all true niches were caused by the diversion of the current by one boulder so as to strike the side of another.

Guttered boulders in typical form are almost as rare as ring-boulders. It requires a boulder having considerable flat or nearly flat surface area on its top to lead to the formation of a gutter. Hence this variety is confined mainly to boulders of large size. The flat surface must have some slight inequalities that will tend to guide the sand and pebbles which the current rolls along. If these irregular features are so arranged that the wearing materials are always guided along the same path they will finally wear it smooth and deepen it more or less, making a sort of gutter across the surface of the boulder. Such smooth-worn grooves are often found where streams flow over solid rock ledges. But they are not so common on boulders. Where they exist under such circumstances that the boulder has clearly not been moved, they show the direction of the current very accurately. There is one fairly good example of this variety in Mattawa, and also several others less noteworthy. But even this best one is not so strongly marked nor so perfect as could be wished. Still, it has the distinct characters of a gutter, and was produced by the process just described. Twenty-five or thirty rods north of the bridge on the east side of the Mattawa river at its mouth are several very large boulders. One is of gigantic size, having dimensions of about 27 feet in length, 24 feet in width and fully 15 feet in height, with probably a third of its bulk buried under ground. It is about 150 feet back from the river and the ground at its base is about ten feet above the water. It is a block of foliated gneiss and shows considerable differential weathering or wearing on its sides where the black hornblendic bands project as ribs nearly horizontal, while the gray quartz-feldspar bands between are relatively depressed by being worn or dissolved out. The top of this great boulder is somewhat uneven, but it slopes in a general way toward the south-southwest or up-stream with reference to the Mattawa. The uneven features of the top surface present their sharper edges and bolder faces toward the northeast. A fairly well developed gutter runs across diagonally from corner to corner in a straight line. Starting at the southwestern corner, it runs up a slope of about 20° to the northeast. Near the lower edge the surface is comparatively plane, having few irregularities and the gutter is scarcely noticeable. But within a foot or two a slight depression appears between very gently sloping sides, and the sand and

pebbles seem to have been gathered into this and so started on their course. This depression was plainly an original feature of the surface of the boulder. But on close inspection it was found that the bottom had been made a little more even and smooth by the sand that had trailed along through it. Then for two or three feet the surface is flat and the sand and pebble current appears to have spread out or divided in two or three parts. Over this space the gutter is not clearly discernible. Then another depression begins and runs three or four feet to the sharp edge of a cavity about one foot in depth. On approaching the edge the gutter becomes very marked, and the edge where the moving materials ran over into the cavity is worn and hollowed out smooth into a shape like the lip of a large water pitcher. After passing out of the cavity and up the face of the boulder again, the worn track reappears directly in line with that just described and becomes more pronounced as it approaches another worn-down notch or pitcher-lip where the gutter passes off the boulder into the air. This worn track crosses the whole extent of the boulder in a direct course, and from its relation to the worn notches in the sharp edges it is plain that the course of the sand and pebbles was from southwest to northeast and not *vice versa*. In sighting backward along the gutter, one looks directly up the course of the Mattawa. At the same time the boulder stands in such a position that it would be openly exposed to higher waters from the northwest descending the valley of the Ottawa. But there are no marks indicating the action of a current from that direction. The top of the boulder at the present time is about 25 feet above the water at low stage.

In another way the giant boulder shows conclusively that a great current of water has played around it. It stands in a sort of basin and rests its lower visible edges against smaller boulders from between which all finer material has been swept away. Open holes now filled with water extend some distance down under the edges of the great boulder. The other boulders now immediately surrounding the great one are mostly small. It seems probable that the great boulder was at first buried more deeply than now. The gutter may, therefore, have been made mostly in the earlier stages of the great river, when sand and gravel would pass more readily over its top. The basin it lies in suggests this, and it is hard to see how sand or gravel could be carried up onto the top of the boulder, as it stands related to the surrounding ground to-day, in sufficient quantities to accomplish such a work.

There is another cluster of very large boulders near the railroad trestle northeast of the great boulder mentioned above. Some of them show faint gutters also and nearly all of them show basins or some other well-marked product of scour. Among smaller boulders the gutter is frequently rep-

resented by notches in the rims of shallow basins. These are well marked sometimes, showing where the sand and pebbles left the basin, and occasionally a notch is found also on the up-stream side where they entered, if the boulder be not too small and its up-stream rim too narrow.

Facetted boulders have plane faces or facets worn smooth. Probably in nearly all cases the facets existed in the rough before the scouring. It would be hard in any given case to prove that this was not true. Still, it is possible that facets have sometimes been made by scour when the facet shape did not previously exist. This variety is fairly plentiful.

Smoothed boulders are far more abundant than all the other varieties put together. Almost every boulder that has a more specific mark of scour shows smoothed surfaces also on other parts. A smoothed boulder is one that has simply been made smooth by scouring and may not have received any other more definite mark in the process. These boulders may have been angular or subangular or rounded before the scouring began, and without having their general form changed they were made smooth over all surfaces alike. In the old channels where the scoured boulders occur almost every one shows more or less of this effect. There are great numbers of scoured boulders along the roadside near the Presbyterian church in Mattawa and farther east for a quarter of a mile. Near the church there are many fine examples of smoothed and basined boulders. Some of them are polished so smooth on one or more sides that they glisten a little in the sunshine even when they are dry. They have a smooth, soft feel under the hand, not like a pane of glass, but rather like a surface of finely embossed leather. Most of the boulders along the road near the church have been moved in road improvement or in clearing ground for buildings. It is probable that the most highly polished parts of the best specimens were previously on the under side or buried, and so protected from the weather ever since they were polished. This suggests that many, at least of the smaller boulders, were turned over and partly buried during the time of the great outlet river. They were scoured and polished and turned over before the river ceased to flow. It is quite possible that other forms of scour may be found on boulders which would suggest the propriety of adding more varieties to the list given above. But the forms found by the author, and examined also by Dr. Bell, seem to be fairly well covered by the names suggested.

One other possible variety deserves mention. When the deep cut was made through the bowldery terrace in Mattawa for the branch railroad up the Ottawa, some very curiously shaped stones were found in the gravelly top layer. Among others was one roughly cone-shaped, but flaring out slightly at the base. It is almost perfectly round on any horizontal sec-

tion and tapers smoothly up to a point about two inches through. Its shape may perhaps be best described by saying that it is like an Irish peasant's hat. The crown is rather pointed and the rim projects downward and outward from it through a very gentle curve. The base or bottom of this stone is flat and smooth and showed no rough surface where it might have been detached from the solid mass. From similar specimens seen before, the writer at once recognized this stone as the detached core of a pothole. It is about ten inches high and rather narrow and slender, and hence suggests a pothole of relatively great depth. But the edges around the base or rim are also apparently worn smooth. This makes it very difficult to account fully for its origin. It seems probable that this stone was bored out of a solid boulder. In that case it is the core left from the making of a ring-boulder. The boulder itself might have been smooth on its bottom before the making of the pothole began, and this would go some way toward explaining the smooth bottom of the core-stone. Such stones as this might be set down as an independent variety of scoured boulders. But so little was learned of the occurrence of this specimen that its place and manner of origin seems to be a matter of some doubt. Nevertheless its smooth and apparently fresh-polished surface suggests that it is a scour product of the rapids of the recent great outlet river. As Dr. Bell has suggested, the ring boulder out of which this "stone hat" or core-stone was bored may be lying close by hidden in the gravelly, bowldery surface layer (three to seven or eight feet deep), which covers that part of the terrace. Mr. Macnab pointed out another curiously hat-shaped stone on a veranda in the village. It had the shape of a "sou'wester," but was clearly the product of differential weathering (perhaps afterwards smoothed in the rapids) rather than of scouring by current action. Dr. Bell deposited the first mentioned specimen in the museum at Ottawa.

Summary.

Some idea of the magnitude of the great outlet river may be gathered from the fact that at Des Epines rapids the mark of its upper limit is quite plain at 50 to 55 feet above the present stream, and the width of the channel at that height is between 600 and 700 feet. The average depth across the channel is 35 to 40 feet, and yet the current was swift enough to produce many of the finest types of scoured boulders. Here and in Mattawa there are other boulder fields as heavily covered as those on which the scoured boulders are found. But they are above the level of the ancient outlet river, and although they were examined closely no scoured boulders were found upon them. There are also other bowldery tracts at low levels at several places above Mattawa. But they are situated

on the shores of lakes or expanded portions of the valley. Some of these too were explored, but were found devoid of scoured boulders. It was only in the rapids of the ancient outlet, where a swift and powerful current flowed over them, and where there was a supply of gravel for the current to roll along that the higher types of scoured boulders were made.

The principal conclusions suggested by the scoured boulders may be summed up briefly as follows, and in these Dr. Bell is in substantial agreement with the author.

1. The modified boulders which show the more pronounced forms of scour must have remained a relatively long time in one position and in a current which was substantially constant in strength and direction of flow in order to have received their deep worn and peculiar markings. This conclusion is further supported by the fact that all the boulders are of hard crystalline rock—mostly of the hardest gneiss and granite.

2. There must have been a constant but not too voluminous supply of gravel or pebbles for the current to roll along over the bowldery bottom in order that the work of scour might be accomplished.

3. Many of the boulders, especially the larger ones, were scoured *in situ* and in some cases the forms of their scour marks show clearly the direction in which the current flowed.

4. All the indications gathered from the boulders of the morainic terrace upon which Mattawa is built show that the scouring current came from the Mattawa valley and not from the Ottawa. And this is true, although the best examples relied upon for this conclusion are situated so as to be equally exposed to any current that might have come down the latter valley.

5. The scoured boulders typified by those at Mattawa and Des Epines rapids constitute a distinct class, which has received secondary modifications of form in consequence of relatively long continued and powerful current action.

6. Beds of scoured boulders like those here described, marking the place of rapids in great rivers no longer in existence, may serve (with due consideration of other attendant conditions) as valuable aids in the study of later Pleistocene history, especially in the bowldery Archæan areas of the north.

In the opinion of the writer the scoured boulders are one of the best of several lines of evidence that clearly establish the existence of the great Nipissing-Mattawa river as the outlet of the three upper Great Lakes in very recent times. The conclusion maintained heretofore by Gilbert, Wright and the author, but on evidence less complete, seems now fairly proven, viz: that for a considerable period of time, while this northern outlet was active, Niagara Falls was robbed of much the larger part of its water.

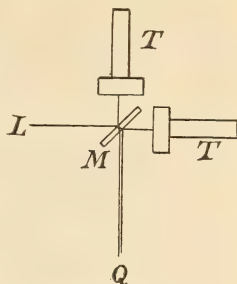
ART. XX.—*Note on the Excursions of the Diaphragm of a Telephone*; by C. BARUS.

1. SOMETIME ago,* while attempting to measure the minimum current audible in a telephone, I encountered a rather remarkable phenomenon: With a continually decreasing current the sound was found to terminate abruptly. A definite interval of silence could be mapped out for gradually increasing currents on either side of zero, and the extent of this interval proved to be 5 to even 15 times the interval of current within which change of sound intensity is appreciable when the limits of the field in question are exceeded. Thus at the margins of the field shades of intensity of about 10^{-7} ampere were acoustically distinguishable, whereas the silent field extended in an average case from -5×10^{-7} to $+5 \times 10^{-7}$ amperes.

I have since been endeavoring to find some reason for this result, and it occurred to me that the interference apparatus described in my last paper† would be adapted for the purpose. It would merely be necessary to replace the helices shown in the figure there given by two ordinary Bell telephones and to attach a very light mirror to the center of the diaphragm of each, in order to meet the conditions of the experiment. These attached mirrors were but 0.05^s in weight and less than 1^{cm} in diameter. Hence they did not hamper the motion of the diaphragm in any way.

Interference measurements of the excursions of the plate are not new; they were made by Salet‡ and more recently by Franke§ with divergent results (20×10^{-6} to 30×10^{-6} cm in the first case and 10^{-7} cm in the last case). In both instances, however, Newtonian interferences were produced, which for the present purposes are manifestly inferior to the Michelson refractometer.

The subject as a whole has been overhauled in a series of interesting researches due to Prof. C. R. Cross, Cross and Mansfield and others|| using a stroboscopic micrometer method.



*T, T, Telephones.
M, Refractometer
plate, Burner beyond
L, Telescope beyond Q.*

* Barus: Phil. Mag. (5), xxxviii, p. 558, 1894.

† Barus: This Journal, February, 1897.

‡ Salet: Comp. Rend., xcv, p. 178, 1882.

§ Franke: Electrotech. Zeitschrift, xi, pp. 288, 1890.

|| Cross and Mansfield: Proc. American Acad., xxviii, p. 93, 1892; cf. Experiment with the microphone, *ibid.*, xxv, p. 69, 1890.

They found that if x is excursion or amplitude of vibration in 10^{-4} cm and y the current in milliamperes,

$$y^2 = 0.305x^{3.26}$$

in very close agreement with their results. They select $y = 2$ as a strong telephone current and thus find the corresponding excursion to be 220×10^{-6} cm, with the remark that the true telephone current is probably somewhat less than this, inasmuch as the field-strength for which the equations hold is somewhat greater than the telephone field.

Now if the current of minimum change of audibility is 10^{-4} milliamperes, as I found, the corresponding change of excursion as called for by the above equation would be 5×10^{-7} cm. Furthermore if the extent of the interval of silence is $\pm 5 \times 10^{-4}$ milliamperes, the smallest excursion obtainable is 1.36×10^{-6} cm. Hence if all these diverse results hang correctly together, the smallest audible excursions of the telephone should be *immeasurable* even with Michelson's refractometer using sodium light. In other words, the sounds should emerge out of the region of silence without producing any disturbance of the interference fringes due to the mirror attached to the telephone diaphragm. This is the case.

2. Putting the telephone in circuit with the secondary of a small induction coil, the primary was supplied with the smallest current sufficient to actuate the interruptor. The telephone was heard to respond quite audibly even when the secondary was left open, for the capacity of the wires was favorable. By closing the secondary circuit with a very large resistance, preferably by putting the fingers in the gap, the sound could be increased to any degree by greater or less pressure of the hand at the contact.

The result with one telephone in circuit showed no change of clearness of the interference fringes when the circuit was left open, although the signal in the telephone (about 50 vibrations per second) was distinct to the ear. I then moved the telescope for observing the fringes to about 6 feet from the telephone and controlled the circuit from this distance. The fringes did not disappear nor indicate motion even when I heard the responding telephone at the telescope or even further away. They became gradually blurred when the circuit was more and more closed with the fingers, but they vanished only for sonorous noises. On the other hand, shouting or loud singing at the distance of the telescope always made the fringes disappear, particularly at certain notes. Thinking that the two telephones (although but one was in circuit) might favor visibility by vibrating sympathetically, I replaced one telephone by a plate mirror without affecting the result.

The induction coil was now removed and replaced with a microphone (dust transmitter with a small transformer) placed over a small music box playing into the mouth-piece of the microphone. All this was removed to a distant room. The tinkling of the music could be heard in the telephone but the fringes remained clear. Finally I placed a small siren under the trumpet of the microphone and produced the usual succession from low to high pitch. As a rule, the fringes were only slightly affected. At certain stages, however, a loud cry was heard in the telephone and the fringes vanished: but these stages seemed clearly to be harmonics. Similarly an organ pipe, f'' ($n = 700$), produced strong resonance and a blank interference field.

It follows, therefore, that if attention be confined to telephonic sounds of faint but distinct audibility, the excursions of the diaphragm must be small as compared with the wavelength of sodium light. Since a single fringe corresponds to 30×10^{-6} cm., and since a shifting or tremor of less than $1/10$ fringe is discernible, the excursions of the plate of an ordinary Bell telephone cannot, in the case in question, be greater than 3×10^{-6} cm. They are probably even below 10^{-6} cm.

3. The result with two telephones in circuit was not as I expected to find it, viz: a retention of clearness of the field throughout greater intensities of vibration. If anything, the fringes vanished sooner, and under like conditions were more blurred than for the case of a single telephone in circuit. The reason of this one would naturally seek in a difference in the self inductions of the two telephones, one of which was a more recent Bell telephone and the other an older instrument which had been used by Profs. Blake and Peirce in their early telephone investigations. The plates in diameter, thickness and material were alike, but not the coils. If, however, one inquires specifically into the matter the case is not so clear. Let θ be the *difference* between the lags of the two telephones behind the electromotive force. Let L_1 and L_2 be their self-inductions, R_1 and R_2 their resistances. Let ω be proportional (2π) to the frequency of the note. Then as shown in my last paper,

$$\tan \theta = \frac{L_1 \omega / R_1 - L_2 \omega / R_2}{1 + (L_1 \omega / R_1)(L_2 \omega / R_2)}.$$

The quantity $L_1 L_2 \omega^2 / R_1 R_2$ will usually be large as compared with 1. Thus

$$\tan \theta = (R_2 / L_2 - R_1 / L_1) / \omega.$$

Since, therefore, $\tan \theta$ increases inversely with frequency, and since self-induction is not small as compared with resistance, θ

will not usually exceed a few degrees. Its effect will thus be negligible in view of the usually large values of ω .

Hence it seems more probable that the vibration figures of the two diaphragms are not identical, or that the mirrors do not (with increasing amplitude) move parallel to themselves. There would thus be a rotation of fringes, and the effect is accentuated with two telephones. A decision of the matter must, however, be reserved for stroboscopic work with spectrum monochromatic light.

4. Returning again to the small induction coil, I put an additional telephone in circuit, which throughout the experiment was held to the ear, and then inserted enough resistance (20,000 ohms with a weak primary current) to obtain vibrations only just discernible by the interference method. The effect in general is a widening of the bands (for the elongations are specially visible) together with a blurring of the field as a whole. Under these conditions I observed a permanent displacement of the fringes, which changed sign with the sign of the current, the shifting being about a half fringe or equivalent to 15×10^{-6} cm along the central normal of the diaphragm. The latter is thus more attracted in one case and less in the other, or the position of equilibrium of the vibrating plate does not apparently coincide with its position for no current. Hence the forced vibrations must have been more rapid than the natural frequency of the plate.

It is interesting to compute the increment of force tugging at the plate in these cases. Having given a circular plate of radius r and thickness s , fixed at the edges, the force P in dynes will produce a displacement of f centimeters, where

$$f = \frac{0.6825}{\pi} \frac{r^2}{s^3} \frac{P}{E},$$

E being Young's modulus (2×10^{12} dynes). Putting $r = 2$ cm, $s = 0.016$ cm, $f = 15 \times 10^{-6}$ cm (as just found), the value of P becomes

$$P = 140 \text{ dynes.}$$

This unexpectedly large result for the force at the center of the plate is an explanation of the unexpectedly small excursions of the diaphragm discussed above: for even if the given minimum amplitude of 10^{-6} cm be taken, the force at the center in case of static flexure would exceed 10 dynes.

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ART. XXI.—*The Arctic Sea Ice as a Geological Agent*; by
RALPH S. TARR.

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Nature of Sea Ice.—Floating in the Arctic waters there are two kinds of ice—the sea-made, and the glacier ice. The former develops in the autumn, first freezing over the protected fjords and bays, and later covering the greater part of the Arctic sea. As it freezes it encloses the glacier ice and consolidates the entire water surface into one mass of ice, which remains in this state until spring. The sea-made ice attains a depth of only a few feet, averaging perhaps fifteen or twenty feet. The wind, waves and currents move it about somewhat even in the winter, and by breaking it and piling the fragments on one another make the surface very irregular, greatly increasing the depth of some of the cakes. Moved by the tides and winds, it grinds against the shore and the shallow bottom, thus doing much work of erosion. In the spring, under the warmth of the rising sun, it commences to melt and goes floating away to the southward, where it finally returns to the liquid condition. Then, hundreds of miles to the southward, the individual cakes and scattered floes may introduce the conditions of the ice-bound sea of the north into the southern latitudes even late in the summer.

Nature of Glacier Ice.—Near the glaciers which end in the sea, the surface of the fjords is littered with ice that has been derived from the glacier front. The melting in the warmth of the sun, the movement over an irregular bottom or the buoyancy of the water, make cracks in the glacier; and the action of the waves and sea water at its base undermines the ice cliff, so that there is a constant cracking and falling of bits and blocks of glacier ice. The air is constantly filled with the reports of varying intensity which accompany the breaking off of ice. Now and then a large piece, perhaps a great section of the glacier front, falls away and enters the sea as an iceberg.

This glacial ice, of whatever origin, encumbers the water of the fjords so that navigation even in a small boat is usually difficult. Slowly the ice drifts out to sea, for the summer winds prevail from the glacier-covered land, and hence there is a balance maintained. Were it not for these off-shore winds the glacier would soon fill the fjord with ice, and not being

able to discharge its cargo, would be obliged to push farther out to sea. The sea-ice is made in winter; the glacier ice is mainly supplied in summer. During the spring and early summer the movement of the sea-made ice is active, and then, when it has disappeared, its place is taken by the supply from the glacier.

Influence of sea-made ice on erosion.—The sea-made ice of winter, covering the bays from shore to shore, *protects* the coast from the action of waves, and hence for the greater part of the year prohibits this form of erosion. Even when the ice is broken up and floating away, it protects in nearly the same manner; for the ice cakes and floes prevent waves from forming, and destroy those that have already been formed elsewhere. Even when the wind was blowing, while our ship was in the open sea off the Labrador coast, there was only an almost imperceptible swell, the remnants of the nearly destroyed waves of the ice-free, open water. However, when the ice cakes are more scattered, the waves use them as effective tools, hurling them against the coast and grinding them up and down upon it. Moreover in the last stages a rim of ice clings firmly to the rock at high-tide mark, and no doubt the waves use this in places as a means of prying off fragments of rock.

It would be difficult to balance the protective and destructive action of this sea ice, but I believe on the whole that the average is in favor of protection. Nevertheless the ice is used as a very effective tool, not merely by the action of the waves, which hurl the individual blocks against the shore, but chiefly by the grinding action of the tide. As the water rises and falls the ice is constantly ground against the shore, and that as a result of this it is doing much work is oftentimes clearly illustrated. Nowhere was this better seen during my visit to the Arctic than on the southern side of Baffin Land in White Strait. There the tide rises about thirty feet, and the mud flats, when exposed to view at low tide, were seen to be pitted and gouged in a manner quite closely resembling the surface of the mud flats on the Massachusetts coast after the clam diggers have left them. Carried in by the tide, the ice cakes strike against the muddy bottom and dig a hole, thus stirring up considerable mud, which is driven about by the tidal currents. Stranded cakes were everywhere present, and that they were engaged in the transportation of rock material was often shown by the presence of good-sized boulders, deeply embedded in the mud, where they had been dropped by the melting of the ice.

In this same region the grinding and transporting action of the ice was shown by the boulder beaches. At the head of

narrow and perfectly protected bays, there were beaches of boulders, averaging a foot or two in diameter, and beneath these, forming the bottom of the bay, was mud. No other agent than ice could possibly have placed these boulders in this position, and upon the stranded blocks of ice there were some boulders journeying toward the beach. Similar boulder beaches were found in the valleys of the land, showing that when the land was formerly lower this same ice action was in progress.

There is another way also in which the sea ice aids in the work of erosion on the shores. The rocks of the New England coast are covered with a protective mat of seaweed, barnacles and other forms of life, while the Arctic shores are entirely free from this covering, except in the minute and most protected crevices. Because of the ice grinding on the shore, life is impossible in the intertidal zone, although at a short distance below this, both animal and plant life are extraordinarily abundant. Lacking the protection of this organic mat, the rocks are open to the direct attack of the water, and its agents must, therefore, work with greater rapidity, in a given period of time, than they do upon a similar coast that is protected by organisms.

Erosion by Glacier Ice.—In a less noticeable way the action of the glacial ice is the same. It is used in the same manner as the sea-made ice, and adds to its efficiency both in protecting and destroying; but there are two additional ways in which the glacier ice does work of erosion after it leaves the glacier. In order to understand the first of these it is necessary to know how the icebergs are put forth into the sea. So far as I could observe, there are several ways in which the ice comes from the glacier front. As has been said, some pieces, usually of small size, drop because of surface melting, and others fall because the sea undermines the ice cliffs. Besides these sources of glacier ice there is the effect of the water, which buoys up the front of the glacier until a breaking results, when bergs, usually of large size, proceed from the front of the glacier.

In some cases this process of iceberg formation happens very quietly, and the front merely cracks off and floats away; but much more commonly the breaking is accompanied by a very decided disturbance. The end of the glacier has attained an unstable position; melting or undercutting cracks off a fragment, and the accompanying jar causes others to follow. The air is filled with sounds, as if of musketry, and from the glacier front there is a constant shower of small pieces and large blocks. Whenever a great mass falls away, numbers of others equally large or larger follow very closely. These do not

break and float quietly away, but actually fall forward into the water. Even though the crack started from the bottom there is no other way for the bergs to fall than to go forward. They must then attain a stable position in accordance with their form, and this often causes them to roll over completely, and float away bottom side upward. So a newly-born iceberg may move off from the ice front either upon its side, bottom or top.

Not only are icebergs of massive form sent off from the glacier front, but if they come from a place that has been sufficiently crevassed and melted into irregular outline, the jarring caused by the falling and overturning may in the end completely destroy the berg and leave in its place only a multitude of fragments. One may often see an immense mass fall off from the ice front, and as it turns and rocks, may observe it break, until finally the original berg is entirely destroyed. When the iceberg is more solid, although numerous fragments continue to drop from its surface as long as it moves, it rocks and rolls backward and forward, perhaps for a half hour, before finally becoming quiet, and every piece that breaks off from this mass adds to the cause of rocking.

From the mass of ice thus cast off from the glacier there is sent outward a water wave, high near the ice front, but reduced to a low, almost imperceptible swell at a distance of a few hundred yards. Following this are other ring waves caused by the rocking and continued breaking. Though low, these are very powerful, for, like the earthquake wave, they are deep-seated disturbances, not superficial like the wind wave. When they reach the shore it is whitened by surf as long as the waves continue to arrive. Then, although the surface of the fjord rises and falls only very gently, the shore line resembles the storm-bound coast of the open ocean; and during a stay of several weeks in the fjord near the Cornell Glacier, at the base of the Upper Nugsuak peninsula (Lat. $73^{\circ} 15'$), these were the only good-sized waves that we saw, near the head of the bay. The waves caused by the production of bergs furnishes an additional instance of erosional work which Arctic ice does. Similar though smaller waves are formed when an iceberg runs aground and begins to break because of the jar.

When a berg comes off from the glacier it falls into the sea and rises and falls as it rocks backward and forward. Possibly as it moves it strikes the bottom; and certainly, as a result of the disturbance which it produces in the water, it stirs up the materials forming the bottom. After leaving the glacier front, in the course of its life history, the berg in all probability becomes stranded once or perhaps several times. Each time it touches the bottom it strikes a direct and heavy blow, and then, breaking slightly as the jar passes through it, and perhaps

even falling into fragments, it rocks backward and forward in its effort to regain a stable position, thus striking the bottom again and again, and undoubtedly stirring up much mud by means of the disturbance of the water. Even when not striking the bottom a strong wave is sent down to the bottom, and by this also there must be a disturbance. That these movements of the iceberg are performing work of distinct importance is proved by the muddiness of the water near the stranded bergs. Also in the berg fjords there is always the evidence of floating sea weed which has been detached from the bottom by this means.

In the fjord which I studied in most detail, an interesting adaptation of animal life to this phenomenon was observed. On the face of the nunatak between the two lobes of the Cornell glacier, a colony of gulls had their breeding place. The moment the report of a falling berg of large size passed through the air, these birds left the cliff, and the air was white with these graceful creatures, flying directly, and with much eager chattering, to the front of the glacier, where they settled on the surface of the water and obtained a feast of shrimp and mollusks which had been stirred up and raised to the surface on the detached sea weed. This grinding against the bottom, and the disturbance caused by the wave produced by the falling ice, not only does considerable work of erosion, but also destroys much life. Notwithstanding this constant destruction, and it is certainly very great, the fauna in the bottom of the fjord was found to be abundant and varied.

Transportation by Sea Ice.—The sea ice of all kinds is also doing a great work of transportation. During our voyage along the Labrador coast, we passed through an unusual amount of floe ice. Shortly after leaving the straits of Belle Isle, we encountered it, and were then in the ice almost continuously until we left the American coast a little north of Cumberland Sound. For nearly one thousand miles we were in sight of floe ice, and we therefore had unusually favorable opportunities for observing the conditions of this agent. As would be expected, the great number of floes were pure and white; but there were many that were transporting sediment. Even when the ice was freest from foreign materials it was estimated that about one per cent of the cakes carried debris of some kind. In some cases the ice was perfectly dirty and black with mud, so that at times we mistook cakes for seals and walruses. In other places, in smaller areas, fully fifty per cent of the floe ice in sight was discolored by a greater or less amount of detritus. These dirtier areas were undoubtedly derived from near the coast.

Some of the material that was being transported by the floe ice was very fine in texture, and apparently had been drifted upon the ice by the action of wind; but much of it was too coarse for this origin, and pebbles were frequently seen upon the surface of the cakes. No doubt these coarser materials were in part raised from the shore by the ice as it came in contact with the coast, or passed near it; but probably the material was more commonly furnished by rills and streams from the land. I am certain that in the distance of one thousand miles of ice-covered sea, our ship was within sight of thousands of tons of sediment, which was of course being slowly distributed over the bottom of the sea as the ice drifted southward.

Transportation by Glacier Ice.—Not merely is the floe ice carrying much sediment, but notwithstanding the statements of others to the contrary, the glacier ice is also a very potent agent in this respect. Among the bergs seen in the south it was rare to find one that had sediment in sight; but no doubt these, which had been floating for months, or possibly years, had long since given up their rock-burden to the sea. Along the Greenland coast, however, sediment-laden bergs were abundant, and this was particularly true in the fjords near the glaciers.

The sea face of the Cornell glacier, like that of most others on the Greenland coast, is made of clear ice, almost absolutely free from even the finest sediment, excepting near the land margin, and below the nunatak which furnishes a medial moraine. The same is true of the ice face wherever the glacier ends on the land; but near the glacier bottom, both on the land and in the fjord, the ice bears considerable debris. That this was true of the ice bottom in the fjord was proved by the evidence of dirt and boulder-covered fragments that were floating in the water of the fjord. Some of these were entirely black, and we mistook some low ice masses for islands because of their discoloration. Moreover in one of the bergs which was actually seen to come from the ice front, this fact was definitely proved; for when it came off it turned with its bottomside uppermost, and floated away as a dark, discolored fragment, derived from a glacier whose exposed front was remarkably white.

There are thousands of tons of boulders, gravel and clay sent into the sea from the front of the Cornell glacier every year and much of this passes beyond the fjord out into Baffin's Bay. The sediment supplied to Baffin's Bay is in no small part derived from the bergs that are discharged into it. Some of this may go for long distances, provided the berg is turned bottom side up, although even in this case the water furnished by the melting of the surface of the ice will after awhile wash

the sediment away. When the berg keeps rightside up, as is commonly the case, the debris rapidly escapes into the sea; and before the iceberg has moved far on its journey only clear ice, which of course forms the greater part of the mass, remains to float away. This is no doubt the reason why the southern bergs, even when these have recently turned upside down, as is frequently the case, are found to be free of sediment. They may have started on their journey with tons of debris.

Effect on Climate.—This brief statement of the geological effects of the Arctic ice would not be nearly complete if its effect upon the temperature of air and water were not mentioned. It chills the ocean on the American side, where the movement of the currents is toward the south, and by this means lowers the mean annual temperature of Baffin Land, Labrador and even New England, as everyone knows. In 1896 this effect was very clearly shown. An unusual amount of floe ice in the month of July so chilled the water on the Labrador coast, that the cod fisheries were nearly a failure, because the cod fish would not come into the cold water near the coast. It was also most strikingly shown in early September, when we left the Greenland coast in summer weather, proceeded toward the southwest, and as our first view of the Baffin Land coast saw a snow-covered land. An ice-covered country was warmer than a nearly ice-free land, which, however, was bathed in water that had been chilled by the ice of the Arctic.

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ART. XXII.—*Contribution to the Geology of Newport Neck and Conanicut Island*; by W. O. CROSBY.

THE granite of Newport Neck and Conanicut Island was regarded by C. T. Jackson* as intrusive, and as having altered the Carboniferous shales to siliceous and epidotic slates. Edward Hitchcock† held a similar view; while C. H. Hitchcock‡ has described the granite as post-Carboniferous, and the siliceous slate as intermediate in age between the Carboniferous and the granite.

In 1876, while collecting data for the Centennial Geological Map of Massachusetts, I made a hurried examination of the Newport area, reaching the conclusion that the granitic rocks are more recent than the flinty slates, which they freely intersect, and older than the grits, shales, and conglomerates of the Carboniferous series; and provisionally correlating the flinty slates with the Cambrian beds of the Boston basin. These unpublished views concerning the relative ages and relations of the rocks and the essential distinctness of the flinty slates and the Carboniferous series were fully confirmed by a more detailed study made ten years later, in 1886, in company with G. H. Barton.

Meanwhile, in 1883 and 1884, T. N. Dale§ had made his important contribution to the geology of this region, in which he clearly recognized the three distinct series of rocks, but failed to regard the granite ("protogine") as intrusive in the flinty slate, making it the oldest of the three series. Three years ago (1893) L. V. Pirsson|| studied the rocks of Conanicut Island, apparently paying no attention to the similar formations on Newport Neck, and reached the conclusions that the granite is the youngest rock formation on the island, that it is intrusive in the Carboniferous strata (shales) and that the flinty slate is merely a contact zone between the granite and shales, a portion of the shales which have suffered contact metamorphism through the influence of the granite and show a gradation from the most typical hornstone into unaltered fissile shales. Still more recently (1894) Collie¶ has published a somewhat elaborate account of the geology of Conanicut Island, in which he agrees with Dale in regarding the flinty slate as distinct from the Carboniferous series and older than the granite.

Since the publication of Pirsson's paper, I have desired to re-examine the relations of the granite to the sedimentary

* Geol. Survey R. I., 1840, 40, 89-92.

† Geology of Massachusetts, 1841, 537, 540, 550, 552.

‡ Proc. Amer. Assoc. Adv. Sci., 1860, 119, 121-126, 129-133, 136-137.

§ This Journal, III, xxvii, 217-228, 282-291. || Ibid, III, xlvi, 363-378.

¶ Trans. Wis. Acad. Sci., x, 199-230.

rocks, but have only recently had an opportunity to do so.* That the granite is, in part at least, intrusive in the flinty slate appears to me unquestionable. Pirsson has clearly set forth the evidence for Conanicut Island, showing conclusively that the finer grain of the granite near the contact, the fact that it is at all points firmly welded to the flinty slate, and above all the fact that it forms beautifully clear apophyses and dikes in the latter, admit of no other explanation. Dale appears to have overlooked the fact that the evidence is similar and equally conclusive on Newport Neck. Dale's map of the

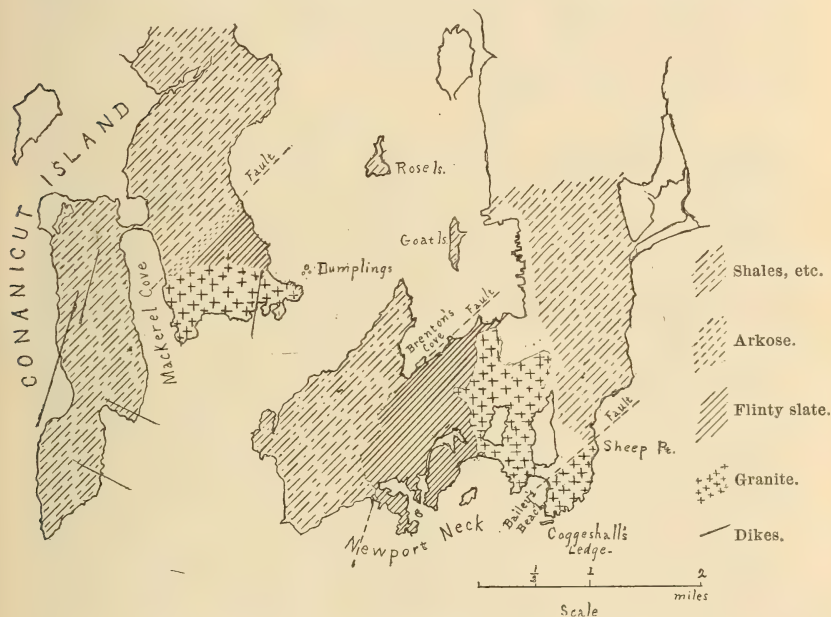


FIG. 1.—Map of Newport Neck and Conanicut Island, modified from Dale.

Neck, reproduced here (fig. 1), is substantially accurate. Along the north-south contact of the granite and flinty slate the fine-grained border of the granite is firmly welded to the slate and clear dikes of similar granite traverse the slate in the vicinity of the contact. The fine-grained, reddish, aplitic granite, whose igneous relations to the flinty slate are so unequivocal, is but the marginal portion or contact zone of a large body or massif of normal, coarse-grained, gray granite. Prof. Barton and I found, however, some evidence of the existence in this region of granitic rocks older than the flinty slate. This evidence consists in the occurrence in the flinty slate, on the north shore of the neck, of several layers of conglomerate containing gray granite pebbles. That the flinty slate owes its

* In this later study I was assisted by Mr. T. A. Watson.

flinty or metamorphic character to the influence of the granite is obvious, and it undoubtedly shows some gradation in the degree of metamorphism as we recede from the border of the granite. But that it grades into the highly fissile Carboniferous shales, as held by Pirsson, cannot be admitted. This is the most critical and at the present time the most distinctly controverted point in the geology of the region. According to Jackson and Pirsson this gradation exists; the flinty slate is simply a more altered part of the Carboniferous shales, and the granite is post-Carboniferous; while according to Dale and Collie the flinty slate is distinctly older than the Carboniferous series, Dale's view differing from that of Collie and the present writer only as regards the relations of this older flinty slate to the granite.

On Newport Neck the flinty slates and the Carboniferous shales are certainly very strongly contrasted, both lithologically and stratigraphically. The former are exceedingly massive gray rocks of almost flinty hardness, rarely exhibiting anything approaching a thin-bedded or shaly structure and with a prevailing east-west strike and approximately vertical dip. The latter are soft, fissile, greenish, greenish-gray or purplish shales with a prevailing north-south strike and moderate easterly dip. Each series holds its characters perfectly up to the common boundary, which is a very obvious fault line. From the granite westward to this line the metamorphic character of the flinty slate diminishes so slightly as to suggest that the granite may underlie the entire area at no great depth. The flinty slates, owing to their superior hardness, form, like the granite, a broken and ledgy tract, which rises boldly above the low and swampy ground underlain by the shales. The stratigraphic discordance is perfect, and indications of a lithological gradation are wholly wanting, although it might be claimed, since the nearest outcrops are thirty feet apart, that a very abrupt gradation is still a possibility. The Carboniferous age of the shales is unquestioned, while it may safely be asserted that the flinty slate resembles no other formation in New England so closely as the Middle Cambrian slates of the Boston basin, many of the ledges being indistinguishable from the more characteristic outcrops of the Blue Hills.

These phenomena are repeated in all essential features at the south end of the Cliffs, between Sheep Point and Bailey's Beach. In going south along the east shore we pass abruptly, near Sheep Point, from Carboniferous shales that are in part greenish gray and in part black and highly carbonaceous, affording an abundant Carboniferous flora, to a compact greenish to grayish tough rock, with occasional bedding lines and streaks of conglomerate, which is undoubtedly equivalent to the flinty slate of Newport Neck. About half way from

Sheep Point to Coggeshall's ledge we pass from the metamorphic slate to the granite. The contact is beautifully exposed and typically igneous, the granite being clearly the newer rock. The granite is bordered by a felsitic or microcrystalline layer four to six inches wide penetrating the slate very irregularly, and forming numerous dikes six inches to three feet wide. The two rocks are firmly welded together. Following the granite around the shore to Bailey's Beach, we come again, at the east end of the beach, upon the metamorphic slate; but the contact is not exposed, what Dale has described as a contact being, apparently, a dike of greenish slaty trap in the granite. The north-south strike and high dips of the unaltered Carboniferous strata north of Sheep Point suggest a northeast-southwest fault between the older and newer slates almost as plainly as on Newport Neck.

On Conanicut Island the metamorphism of the ancient slate series is more marked near the granite, and there is a more distinct gradation in metamorphic character, than on Newport Neck. We pass from the granite to a massive semicrystalline greenish rock, almost destitute of recognizable bedding lines and netted with veinlets of quartz and epidote. This grades into the normal flinty slate similar to that of Newport Neck, which is in part distinctly bedded, with approximately east-west strike and vertical dip. Pirsson states that "every transition can be found between unaltered shales and the most solid of hornstones in contact with the granite, but not, however, in any one place or exposure." I find, on the contrary, that, so far as the shales are concerned, they show absolutely no gradation in the degree of metamorphism along lines normal to the border of the granite; and the metamorphism is quite as marked miles away from the granite as in its vicinity. The drift mantle north of the granite and metamorphic slate is practically continuous from shore to shore; and Pirsson is able to point out only one exposure where the supposed gradation of the shales into the typical flinty slate or hornstone can be observed. He says: "In the northeast (printed northwest) corner of D 5 (figure 2) just south of Mr. Green's barn occurs a long outcrop extending toward the south. At the north end the shales, although still retaining a fissile character, are very much gnarled and toughened, and as one proceeds southward they pass within two or three rods into compact hornstones. From this exposure it may be seen that the loss of the shaly character and transition into hornstone occurs within a very short distance." I have closely scrutinized this outcrop; but find myself unable to accept Pirsson's interpretation of it. It seems to me to belong wholly to the flinty slate, the supposed gradation being simply one of the many local variations of this formation. But even in this sense I can see no real gradation.

From the north end of the ledge southward the slate is rather unusually but uniformly shaly for about twenty feet, and then we pass with absolute abruptness to the most typical tough, massive, and seemingly unstratified hornstone, which forms all

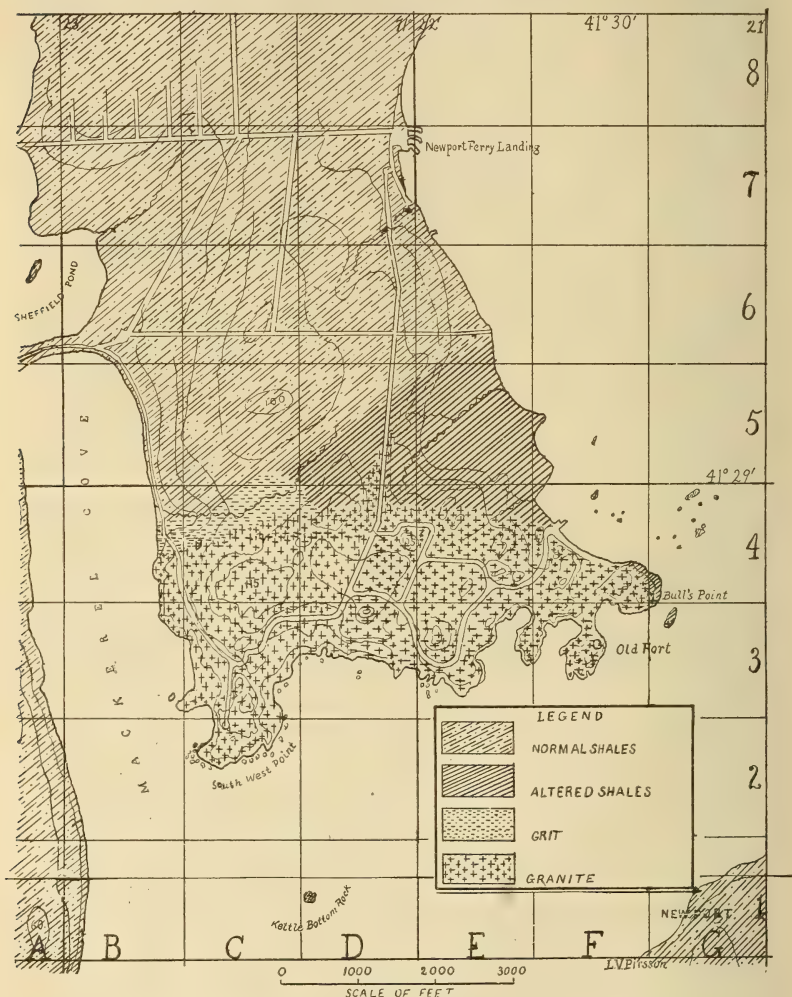


FIG. 2.—Map of a part of Conanicut Island, by L. V. Pirsson.

the remainder of an extensive outcrop. The abruptness of this passage from the less to the more metamorphic slate suggests a small fault. This outcrop is about one thousand feet from the nearest exposure of granite, and nearly two thousand feet from the main body of granite; and it certainly seems improbable that the metamorphic influence of the granite,

having extended so far with approximately uniform intensity, should then die out or show a very marked diminution within a few feet or yards. A rapid change near the granite and a slow change at a distance would appear to be a better expression of the general law in such cases.

Considered by itself, this evidence is, perhaps, inconclusive, since to the northward there are no outcrops for a long distance. But it is important here to take note of the bed of arkose (called grit by Pirsson and quartz and clay aggregate by Dale) which Dale, Pirsson and Collie have mapped on the east shore of Mackerel Cove, between the granite and shales (figure 2). Each of the maps referred to shows the arkose, which has a breadth on the shore of at least 400 feet, as extending in a northeasterly or diagonal direction toward the eastern shore of the island, and ending abruptly with a greatly increased breadth when less than half way across the island. After examining the outcrops of arkose on the shore of Mackerel Cove, Mr. Watson and I were searching along the road north of Mr. Green's barn for outcrops, hoping to find something that might assist in the interpretation of the outcrop upon which Pirsson's argument so largely rests, when our attention was attracted by the abundance of arkose, identical in character with that on the shore, in the stone walls and scattered in angular masses up to three feet in diameter over the adjoining fields. Following up this clue, we found that the arkose debris is abundant over the entire slope from the road to the east shore for a breadth of 400 to 500 feet north of the last outcrops of the flinty slate; and on the shore, from the flinty slate on the south to the green and fissile shales on the north, an estimated distance of four hundred feet, there are many angular masses of the same coarse, dark arkose. In the light of these facts it cannot be doubted that the arkose extends entirely across the island in a belt of approximately uniform breadth (four hundred feet more or less) between the unaltered green shales on the north and the flinty slate and granite on the south (fig. 1). Its unconformable relations to these older rocks is indicated by its passing obliquely from the one to the other.

This continuous belt of arkose separating the flinty slate from the unaltered green shales seems to materially strengthen the conclusion stated above with regard to the significance of the ledge south of Mr. Green's barn. The idea of an important or significant gradation is ruled out for the simple reason that there is nothing for the flinty slate to grade into. The arkose is quite out of the question in this connection, if for no other reason, because it is so clearly newer than the granite of the debris of which it is chiefly composed, and, therefore, newer than the metamorphism of the flinty slate which the granite intersects. That the arkose is not a fault-breccia, but a

regular member of the Carboniferous series, seems to be proved by the following considerations: First, it is composed chiefly of granite debris and not of fragments of shale, as it undoubtedly would be if due to the mutual friction of the granite and shale. Second, it is essentially identical with the arkose which elsewhere in the Narragansett Basin clearly underlies the green and gray shales, as on Rose Island, Coasters Harbor Island, and Sachuest Neck, and on the mainland at Tiverton and Fall River; and is quite certainly, as held by Dale, Collie, and others, the basal member of the Carboniferous series. Collie says, "the arkose (of Conanicut Island) is not a local exposure. It is everywhere present, lying between the granite and the overlying schist (shale). Well-diggers state that in all parts of the island they invariably come upon a layer of rotten granite before the hard granite is reached."

The arkose clearly follows the northern border of the granite and flinty slate, cutting across the north-south strike of the shales. This marked discordance of the arkose and shales suggests a northeast-southwest fault between them, with the downthrow on the northwest. Of this fault we have abundant evidence on the shores, and especially on the eastern shore, where we find between the arkose and shale a magnificent development of fault breccia. For a breadth of about fifty feet the green and black shales are completely brecciated, the fragments being cemented by an imperfectly lithified argillaceous paste; and north of this crushed zone are many minor shear planes approximately parallel to the main fault and transverse to the strike of the shales. This great fault evidently belongs to the same system as those on Newport Neck, the chief difference being that in the case of the latter the upthrow has been sufficient to carry the arkose wholly above the present plane of erosion. The relations of the arkose on Conanicut Island point distinctly to the conclusion that the faults date from the time when the Carboniferous strata were folded and the rigid floor of granite and flinty slate was upheaved, that is, during the Appalachian revolution.

Concerning the southwest extension of this fault nothing can be positively asserted. The non-occurrence of the ancient slate and granite on the Beaver tail portion of the island suggests a fault parallel with the major axis of Mackerel Cove. The trap (minette) dikes (fig. 1), as Collie has pointed out, cut both the granite and the shales, and must be post-Carboniferous, probably dating, like the great dikes of the Paradise Rocks, from the folding and faulting of the strata. This completes the parallelism with the geology of the Boston Basin, where the granitic rocks—granite, diorite, and felsite—are clearly newer than the Cambrian slates and older than the Carboniferous strata, and the trap dikes are post-Carboniferous, except a few which antedate the granite.

ART. XXIII.—*The Estimation of Molybdenum Iodometrically*; by F. A. GOOCH.

[Contributions from the Kent Chemical Laboratory of Yale University, LXII.]

IN a former paper from this laboratory* several modes of applying hydriodic acid to the reduction of molybdic acid were studied. It was found, first, that the digestion process of Mauro and Danesi† is of very limited applicability, owing to the fact that the reaction of reduction is reversible. Secondly, it appeared that the use of the same reaction by Friedheim and Euler‡ in a distillation process, so arranged that the iodine set free in the reduction might be caught in the distillate and titrated to serve as the measure of the reducing action, was not sufficiently regular because of inattention to minor details. It was shown that by taking care to adjust the conditions constant results might be obtained. Thirdly, the fact was developed that by simply boiling the solution under well defined conditions in an ordinary Erlenmeyer flask, partly closed by a simple trap, the reduction of the molybdic acid proceeded regularly, and that the addition of standard iodine to the solution made alkaline with sodium bicarbonate served to restore the original condition of oxidation of the molybdic acid. The results of this treatment were shown to be accurate.

In a recent paper§ Friedheim has seen fit to make our modifications of the distillation process the subject of attack. Friedheim's comments upon the third method discussed (as well as upon a subsequent application of the process)¶ are evidently prompted wholly by personal opinion and demand no further attention. With reference to Friedheim's denial of the necessity of modification in the Friedheim and Euler treatment the case is different.

The process of Friedheim and Euler consists, it will be remembered, in treating the soluble molybdate, or the solution of molybdic acid in sodium hydroxide, with potassium iodide and hydrochloric acid in a Bunsen apparatus, boiling until the solution is of a clear green color, collecting the iodine distilled in potassium iodide, and titrating it with sodium thiosulphate. We found that the development of the green color was not a sufficient criterion of the exact reduction of the molybdic acid to the condition of the pentoxide and of the removal of the iodine which should be theoretically set free. To accomplish that end we found it safer and more convenient to

* Gooch and Fairbanks, this Journal, IV, ii, 157, 1896.

† Zeitschr. für anal. Chem., xx, 507. ‡ Ber. d. d. Chem. Gesell., xxviii, 2066.

§ Ber. d. d. Chem. Gesell., xxix, 2981.

¶ An Iodometric Method for the Determination of Phosphorus in Iron, by Charlotte Fairbanks.

start the distillation with a definite volume (40cm^3) of liquid and boil until a definite volume (25cm^3) was reached, care being taken with regard to the strength of acid and the excess of potassium iodide employed. Experience showed unmistakably that in order to avoid the decomposing action of the air upon the hot vaporous hydriodic acid in the retort, it was necessary to go beyond the measures advised by Friedheim and Euler (namely, to warm the retort and its contents slowly, heating to boiling only when the connecting tube was well filled with iodine vapor and the tendency toward back-suction of the liquid in the receiver began to appear) and to conduct the operation in a simple little apparatus (the retort holding about 100cm^3) put together entirely with sealed and ground joints, as shown in the figure of the former paper, so arranged that a current of purified carbon dioxide could be passed through retort and receiver during the distillation. With this apparatus we were able to determine with accuracy the point of concentration at which the free iodine left the liquid, the molybdic acid having been converted to the condition of the pentoxide. It was found that if dependence is placed upon the occurrence of the so-called clear green color of the liquid to determine the end of the distillation, it may frequently happen that free iodine remains in the residue. This takes place, it will be observed, in the atmosphere of carbon dioxide, so that the presence of the free iodine can by no possibility be attributed to the action of atmospheric air upon the hydriodic acid remaining after the distillation is complete. On the other hand, it appeared that, if the distillation is pushed too far, the molybdenum pentoxide may be still further reduced with consequent evolution of more than the expected amount of iodine. The attainment of an exact degree of reduction with the expulsion of the corresponding amount of iodine becomes, therefore, a matter of chance unless further precautions are taken. We found in our experiments that, if amounts less than 0.3 gram. of the molybdic acid are introduced in soluble form into the 100cm^3 retort with a not too great excess of potassium iodide, and the 40cm^3 of liquid so constituted that 20cm^3 of it shall be water and 20cm^3 the strongest hydrochloric acid, the reduction proceeds with a fair degree of regularity in the manner expected. We found it important to restrict the excess of potassium iodide so that it shall never exceed the theoretical requirement by more than 0.5 gram.

Our determinations with the pure molybdenum trioxide showed errors varying from $.0010$ gram. + to $.0007$ gram. - ; the variations from theory in the experiments with ammonium molybdate ranged from $.0011$ gram. + to $.0011$ gram. -. If these results are compared with those given by Friedheim and Euler, the advantage is a little in favor of the latter ; but a

scrutiny of the figures given by Friedheim and Euler develops the fact that the apparent accuracy of their work is founded upon miscalculations. This fact was known to us at the time of our former writing, but we did not consider it essential then to make the matter public. The recent attack of Friedheim makes that course now necessary.

Herewith is reproduced a table of results obtained by Friedheim and Euler in the test of their method upon ammonium molybdate, shown by analysis to contain 81.49 per cent. of molybdenum trioxide. The figures which are incorrect are enclosed in brackets :

Original Figures of Friedheim and Euler.

| Molybdate taken. gram. | Na ₂ S ₂ O ₃ used. cm ³ . | MoO ₃ found. gram. | Per cent of MoO ₃ referred to molybdate taken. |
|------------------------------|---|-------------------------------------|--|
| 0.2674 | 30.8 | 0.2184 | [81.71] |
| 0.4418 | 50.8 | 0.3601 | 81.51 |
| 0.4075 | [40.7]* | 0.3317 | 81.40 |
| 0.3281 | 37.33 | 0.2644 | [81.85] |
| 0.4340 | 49.43 | 0.3502 | 81.69 |
| 0.4098 | 46.63 | 0.3304 | 81.67 |
| 0.4305 | 49.08 | 0.3478 | [81.78] |

Appended is a recalculation of the percentage of the trioxide found, with columns showing the percentage error and the error stated in fractions of a gram. Changes from the figures of Friedheim and Euler are in heavy-faced type.

Recalculation of the Results of Friedheim and Euler.

| Corrected per cent of MoO ₃ found, referred to the molybdate. | Error in per cent of MoO ₃ found compared with MoO ₃ taken. | Error of MoO ₃ . gram. |
|---|---|---|
| 81.68 | 0.23 + | 0.0005 + |
| 81.51 | 0.03 + | 0.0001 + |
| 81.40 | 0.12 — | 0.0004 — |
| 80.58 | 1.12 — | 0.0030 — |
| 80.69 | 0.99 — | 0.0035 — |
| 80.62 | 1.05 — | 0.0035 — |
| 80.79 | 0.86 — | 0.0030 — |

These figures of their own (properly calculated) are sufficient to show the inadequacy of the method of Friedheim and Euler. We ourselves were occasionally able to get results from the method of Friedheim and Euler quite as good as these ; it must be said, however, that most of our results

* Probably 46.7.

obtained by their unmodified method have been even worse than their own.

In another series of six determinations, in which molybdenum trioxide was the starting point, Friedheim and Euler were more successful, the errors varying from 0.0006 grm. + to 0.0006 grm. -. Thus Friedheim and Euler establish by their own results the fact that the hitting of the right point at which to stop their process of boiling is a matter of chance. In spite of the probability that some of the iodine which they found in the receiver was liberated by atmospheric action, the fact remains that their results are in many cases very low. That is, they did not boil long enough.

The difficulty appears again in the modification of their method which Friedheim and Euler apply to the determination of molybdenum trioxide associated with vanadium pentoxide*, namely, the distillation with phosphoric acid and potassium iodide of the residue left after reducing the vanadium pentoxide by hydrochloric acid and potassium bromide, according to the method of Holverscheid. We reproduce the part of their table which refers to the determination of the molybdenum, adding, however, columns containing the errors and corrected percentages.

| MoO ₃ taken. | MoO ₃ found. | Per cent MoO ₃ F. and E. | Error. grm. | Per cent MoO ₃ . Recalculated. |
|----------------------------|----------------------------|---|----------------|---|
| 0.15037 | 0.15005 | 99.79 | 0.00032 — | 99.79 |
| 0.16895 | 0.16879 | 99.90 | 0.00016 — | 99.90 |
| 0.17758 | 0.17729 | 99.84 | 0.00029 — | 99.84 |
| 0.24975 | 0.24962 | 99.95 | 0.00013 — | 99.95 |
| 0.33151 | 0.33607 | [99.87] | 0.00456 + | 101.38 |

Four of the five determinations are accurate, but the fact that all figures are carried out to the fifth decimal place does not keep three good sized figures out of the error column for the fifth determination.

It is hardly necessary, in the light of a comparison of the results of Friedheim and Euler with ours, to discuss further the unreliability of the unmodified process. The necessity of a proper control of the volume, strength of acid, and excess of potassium iodide, as well as proper protection from atmospheric oxidation, is real.

On a former occasion the unpleasant necessity presented itself† of pointing out the fact that certain unfounded criticisms on the part of Friedheim and Meyer were based upon an unfortunate use by them of impure reagents; the difficulty in the present case, for Friedheim and Euler, seems to reside in the arithmetical process.

* Ber. d. d. Chem. Gesell., xxviii, 2072.

† Gooch and Browning, this Journal, xlv, 334.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Density of Helium.*—RAMSAY has continued his researches on the gaseous constituents of minerals. While the gas from clèveite contains some nitrogen and no hydrogen, that from bröggerite, samarskite and fergusonite, obtained by heating the mineral in a vacuum, is rich in hydrogen but contains only an infinitesimal amount of nitrogen. From one gram of clèveite 7.2^{cc} of helium were obtained; while from one gram of bröggerite less than 1^{cc}, from one gram of samarskite only 0.6^{cc} and from fergusonite (by heating alone) only 1.1^{cc} per gram were obtained. This latter gas contained hydrogen 54.7, carbon dioxide 13.9 and helium 31.2 per cent. For the density determinations the gas was purified by treating it with caustic soda and then passing it over red hot copper oxide, soda-lime and phosphoric oxide. The helium from bröggerite and clèveite mixed had a density of 2.218; and after a second treatment one of 2.133. That from bröggerite alone gave 2.181. That from samarskite, obtained by heat alone, 2.121; obtained by fusion with HKSO₄, 2.122; falling to 2.117 after a second treatment, and to 2.114 after a third one; the mean being 2.118. The gas from fergusonite obtained by heat alone gave in one sample 2.147, in another 2.139 and in a third 2.134; the mean being 2.140. It may be, therefore, that helium from various sources is not quite homogeneous, different samples varying in density. The light given by a vacuum tube containing clèveite gas has a richer orange-yellow shade than that from the other three minerals. Moreover this clèveite gas shows a special set of fairly strong lines between the green and the blue which have never been observed in the gases obtained from the other minerals.—*Proc. Roy. Soc.*, lix, 325, 1896. G. F. B.

2. *On the expansion of Helium and Argon.*—By means of thermometers containing air, hydrogen, argon and helium respectively, KUENEN and RANDALL have determined the relative coefficients of expansion of these gases, at the temperatures of the melting point of ice, and the boiling points of water, chlorbenzene, aniline, quinoline, and bromnaphthalene. The helium used had a density of 2.13, and the argon, which was prepared from air by means of magnesium, a density of 19.99. From the pressure readings at 0° and at 100°, the mean coefficient for helium between these limits was found to be 0.003665, for argon 0.003668, and for air 0.003663. Using these figures, the authors calculated the boiling points of the other substances above mentioned and found them to accord closely. Though no very high precision is claimed for these results, they serve to show that argon and helium may be regarded in so far as perfect gases.—*Proc. Roy. Soc.*, lix, 198, 1896. G. F. B.

3. *On the electric discharge in Argon and Helium.*—Experi-

ments have been made by COLLIE and RAMSAY to determine: 1st, the distance through which the electric spark will strike through argon and through helium at atmospheric pressure; and 2d, the pressure under which the spark discharge changes into a ribbon-like discharge in these gases, as compared with others. Even with argon it was found that the length of the spark was considerably greater than with air, oxygen or hydrogen; while with helium the distance through which the spark would pass was remarkable. Thus while in oxygen the spark-length was $23\cdot0^{\text{mm}}$, in air $33\cdot0^{\text{mm}}$ and in hydrogen $39\cdot0^{\text{mm}}$, in argon it was $45\cdot5^{\text{mm}}$ and in helium probably $250\text{--}300^{\text{mm}}$. In helium the discharge was a blue ribbon of flame not showing the D_3 line very distinctly. Moreover these experiments showed that the spark discharge changed to the ribbon discharge at some definite pressure in all gases. Thus in air it occurred at 73 or 74^{mm} ; in hydrogen at 42 or 43^{mm} ; in oxygen at 81^{mm} ; in carbon dioxide at 92 or 94^{mm} ; in cyanogen at 23^{mm} ; in nitrogen at 33^{mm} ; in carbon monoxide at 49^{mm} ; and in helium at 1270^{mm} . Hence helium is different from all other gases in this respect. So that a Plücker tube filled with helium at atmospheric pressure exhibits all the phenomena of a vacuum tube.

In a second series of experiments, made in electrodeless tubes, at different pressures, the object was to determine the quantity of one gas detectible in a mixture with another, and thus to form a judgment as to the adequacy of the spectrum test as an evidence of purity. In hydrogen it was found that at $2\cdot61^{\text{mm}}$ 33 per cent of helium was quite invisible, while at the lowest pressures 10 per cent was barely visible. Conversely $0\cdot001$ per cent of hydrogen is visible in helium at all pressures. Nitrogen $0\cdot01$ per cent is almost invisible in helium; while 10 per cent of helium in nitrogen can be detected only with difficulty. Argon $0\cdot06$ per cent can be detected in helium at all pressures; while 33 per cent of helium is invisible in argon at $2\cdot62^{\text{mm}}$ pressure and 25 per cent is invisible at $0\cdot58^{\text{mm}}$. Nitrogen $0\cdot42$ per cent is invisible in argon at $0\cdot17^{\text{mm}}$ pressure and $0\cdot08$ per cent is invisible at $0\cdot18^{\text{mm}}$, although just visible at $1\cdot05^{\text{mm}}$. Argon 37 per cent in nitrogen is barely visible at any pressure; while in oxygen 2·3 per cent can be distinguished only with difficulty at $1\cdot04^{\text{mm}}$. The luminosity of the argon spectrum is greatly decreased by oxygen, the reduction of pressure having no effect in intensifying it.—*Proc. Roy. Soc.*, lix, 257, 1896.

G. F. B.

4. *On the Gases obtained from Uraninite and Eliasite.*—Observations by LOCKYER show that the gases obtained from the mineral eliasite when heated in a vacuum yield spectra containing the lines of unknown elements as well as of known ones, many of these being probably coincident with stellar and solar lines, although in some cases no coincidences have been observed. He observes that the composition of the gas varies with the stage of the heating process, no trace of D_3 being seen in the first two portions taken, while in the third from the same specimen this

line was quite bright. Indeed in one experiment the product of this heating collected in four stages gave different spectra. The spectrum of the gas from eliasite contains lines indicating a new gas, thus resembling bröggerite and clèveite. The fact that D_3 is not necessarily present would seem to favor the view that the gases from these minerals are complex.

As to uraninite, Lockyer has brought together his notes on the spectra of the gases obtained from this mineral. In addition to the hydrogen lines, he has found in the spectra of these mineral gases all those of the chromospheric lines in Young's list which have a frequency of 100. From wave-length determinations which he has made, he has but little doubt as to the coincidence of several lines in the spectra of these new gases with lines appearing in the chromosphere, the nebulae and the white stars. Probably too some often observed lines, not so far identified, belong to gases in the chromosphere not hitherto recorded. Since, as the result of diffusion experiments made on clèveite gas at different pressures, Runge and Paschen concluded that the gas giving the line D_3 was heavier than that giving the line 5015.7, the author regarded it as important for stellar classification to settle the matter and has made experiments in which the pressures were maintained the same. He concludes that if a true diffusion of one constituent takes place, the component giving D_3 is lighter than the one giving the line of wave length 5105.7; this being in harmony with solar and stellar results.—*Proc. Roy. Soc.*, lix, 1-3, 4-8, 342-343, 1895-6.

G. F. B.

5. *On the preparation of Lithium and on a quick Nitrogen Absorbent.*—It has been shown by WARREN that if dry lithium hydroxide is heated in an iron tubulated retort, and metallic magnesium is added from time to time in small pieces through the tubulure, metallic lithium distils over. If the carbonate be used, the metal obtained is contaminated with the carbide, which evolves acetylene in contact with water. The author also points out that a material absorbing nitrogen with great avidity and therefore of use in preparing argon from the air, may be obtained by reducing in an atmosphere of hydrogen and at as low a temperature as possible, a mixture of magnesium powder and calcium or barium hydroxide saturated with a strong solution of lithium.—*Chem. News*, lxxiv, 6, July, 1896.

G. F. B.

6. *On the Artificial Production of Diamonds.*—By carburetting iron, fusing it in the electric furnace and allowing it to fall into mercury 10^{cm} deep covered with a layer of water 20^{cm} thick, MOISSAN has obtained granules of irregular shapes and also spheres or ellipsoids, both saturated with carbon. While however the former contained no carbon of high specific gravity, the latter contained both black and transparent diamonds, some of which, though microscopic, showed remarkably regular crystalline forms. Subsequently larger masses of the carburetted and fused iron were allowed to fall into water and mercury at the bottom of a pit-shaft 32 meters deep. But these conditions were not

favorable to the production of spherical masses of iron. When the falling globules touched the tub containing the mercury, or the earth outside, they broke up with a flame into scintillating globules giving a report like a rifle. When the fused carburetted iron was run into a small cylindrical cavity in a large mass of iron or copper, the fused metal was very rapidly cooled and diamonds were obtained mixed with graphite, the yield however being small. Moissan has also observed that the so-called black diamond, included in transparent diamonds from Brazil, is a variety of carbon differing from the diamond. When such diamonds are pulverized and heated in oxygen at 200° below the ignition-point of the diamond, the black matter burns away, leaving the residual diamond white.—*C. R.*, cxxiii, 206, 210, July, 1896.

G. F. B.

7. *On the preparation of Metallic Hydroxides by Electrolysis.*—Experiments by LORENZ have shown that metallic hydroxides can be easily prepared by electrolysis. The bath used is an aqueous solution of potassium or sodium chloride, sulphate or nitrate, according to the ease with which the desired hydroxide is formed in these solutions. A platinum plate constitutes the cathode, and a plate of the metal whose hydroxide is to be obtained, the anode. By stirring constantly the solution, the hydroxide comes down as an insoluble precipitate. Thus an anode of copper in potassium chloride solution gives a yellowish-red precipitate of cuprous hydroxide, while in a solution of potassium nitrate it yields a blue precipitate of cupric hydroxide. In this way the hydroxides of silver, magnesium, zinc, cadmium, aluminium, lead, manganese and iron are readily obtained. Mercury in a bath of potassium chloride gives no precipitate, calomel being formed; but in a bath of the nitrate, a black precipitate is produced. Thallium in baths of potassium salts is covered with suboxide, a brown precipitate of hydroxide being gradually formed. Tin in a bath of chloride, sulphate or nitrate yields orthostannic acid, which is thus easily obtained pure. Antimony and bismuth thus treated become covered with a grey coating, no hydroxides resulting. Nickel in a nitrate bath, is quickly covered with a black coating; but in a chloride bath the green hydroxide is easily obtained. Since the method is applicable to the preparation of hydroxides insoluble in water, the hydroxyl ions and the metal ions being formed in equivalent proportions, the hydroxide is obtained in neutral solutions; a great advantage over the chemical method, in which it is necessary to wash the hydroxide free from alkali. Moreover as the precipitated hydroxides are formed in the solution and not at the electrodes, the latter do not become foul and a large quantity of the product can be prepared with the same strength of current and solution. Evidently the anode should be made of pure metal in all cases.—*Zeitschr. Anorg. Chem.*, xii, 436, July, 1896. G. F. B.

8. *On "Excited" Metals, and on Excited Aluminum as a Reducing agent.*—A metal the activity of which is increased by

contact with another metal WISLICENUS' proposes to speak of as an "excited" metal, in place of "metal couple" suggested by Gladstone and Tribe. To excite aluminum with mercury, aluminum powder is covered with a one-tenth saturated solution of mercuric chloride in absolute alcohol; and after a few seconds the product is washed with absolute alcohol and ether. Such excited aluminum is especially adapted for reduction in neutral solutions; an aqueous alcoholic solution of nitrobenzene yielding aniline in this way, unless the temperature be kept at 40° to 50° when β -phenylhydroxylamine is formed; a better yield of the latter (85 to 90 per cent of the theoretical) being obtained by using a cooled solution of the nitrobenzene in ether. Ethyl oxalate thus treated yields ethyl glycolate and alcohol.—*J. pr. Chem.*, II, liv, 18, August, 1896.

G. F. B.

9. *The Constants of Nature*. Part V. *A Recalculation of the Atomic Weights*. New edition, revised and enlarged. Smithsonian Miscellaneous Collections. 1075. Washington, 1897.—Prof. Clarke's new and carefully elaborated edition of the recalculation of the atomic weights, which has recently been issued, will be welcomed by the many chemists who have been benefited by his earlier labors in this line.

10. *Compact apparatus for the study of electric waves*.—Prof. JAGADIS CHUNDER BOSE describes a very compact apparatus for this purpose, which consists in using a spiral steel spring connected with a battery and a galvanometer. The spiral spring serves under different degrees of compression as a *coherer* instead of particles of metals, which have been used by Brady and also by Lodge. The oscillator consists of a central ball of platinum and two small balls one on each side of the central ball. The oscillating sparks occur between the small balls and the central ball. The author has repeated most of the ordinary optical phenomena by means of electric waves.—*Phil. Mag.*, January, 1897.

J. T.

11. *A new formula for spectrum waves*.—J. J. BALMERS' empirical formula for calculating the wave length of hydrogen has awakened great interest; for values calculated from his formula agree very closely with the observed values. In this article he reviews the work of Kayser and Runge on formulas for expressing the periodicity of spectrum lines, and also the recent work of Rydberg; and he gives a modified formula. He is convinced that in the spectrum formula originally given the constant n should be extended by a constant fraction. He therefore modifies his formula and writes it

$$\lambda_n = a \frac{(n+c)^2}{(n+c)^2 - b}$$

in which a has the value of 2300 Ångström units. The paper includes an estimation of the values of c .—*Ann. der Physik und Chemie*, No. 2, 1897, pp. 380-391.

J. T.

12. *Discharge rays and the connection between them and the Cathode and Röntgen rays.*—M. WILLIBAD HOFFMANN has studied the luminescence produced in various substances by means of electric discharges of various forms and has traced the phenomena from its beginning in air to its manifestation in rarified media.—*Ann. der Physik und Chemie*, No. 2, 1897, pp. 269–299. J. T.

13. *Large storage battery.*—Professor TROWBRIDGE has had constructed a storage battery of ten thousand cells for the Jefferson Physical laboratory. The details of the battery have been completed with great skill by the mechanician, Mr. G. M. Thompson. The battery gives a voltage of at least twenty thousand, with a current of eight amperes. It is unable to light a Crookes tube. The lowest voltage which will satisfactorily produce the Röntgen rays appears to be one hundred thousand volts. The battery can be employed with great success to charge Leyden jars in parallel and to discharge them in series. A small electric motor is employed to revolve a suitable commutator in order to discharge the Leyden jars rapidly in series. The apparatus is a modification of that first used by Planté. It enables one to study quantitatively the high electromotive force necessary to produce the Röntgen rays. An oscillatory discharge of electricity through a Crookes tube appears to be prejudicial for the development of the X-rays. The best results are obtained without a condenser in series with the Crookes tube. This seems to show that the electrostatic polarization is largely instrumental in the generation of the Röntgen rays. J. T.

14. *Outlines of Electricity and Magnetism*; by CHARLES A. PERKINS. 277 pp. New York, 1896 (Henry Holt & Company).—The author has presented in this little volume the prominent phenomena and principles of electricity and magnetism. Further, he has attempted, and in the main with success, to show how modern theories serve to explain the observed phenomena and to bring out the essential relation between them. Numerous illustrations and analogies are employed and in general in such a way as to materially aid the elementary student to obtain clear ideas of the subjects under discussion.

II. GEOLOGY AND MINERALOGY.

1. *Principal features of the Geology of Southeastern Washington*; by ISRAEL C. RUSSELL. (Abstract furnished by the author.)—The following note gives a brief statement of the results of a six-weeks reconnoissance in the southeastern portion of the State of Washington made for the U. S. Geological Survey.

Practically all of that portion of Washington which lies south of the Big Bend of the Columbia is occupied by a succession of basaltic lava flows. This is a portion of a vast lava-covered region embracing northern California, central and eastern Oregon, central and southeastern Washington and southern Idaho. The great fissure eruptions which supplied the Columbia lava, as the basalt is termed, occurred in the Miocene.

The Columbia lava in Washington to the west of the Columbia and south of the Big Bend, as ascertained during a previous reconnaissance, is broken by extensive faults and the blocks thus formed variously tilted. In the region here treated, however, the basalt is horizontal over extensive areas, and deeply dissected by Snake river and its tributaries.

Many lava sheets, one resting on another, were seen. Between some of the flows there are widely extended sheets of lacustral clays, sand, gravel, volcanic dust and lapilli. In some instances leaves and the silicified stumps and trunks of trees occur in these layers.

The Columbia lava flowed about the bases of the mountains of eastern Washington and the adjacent portion of Idaho, in a series of inundations which covered the low country to the south. The level basaltic plateau meets the mountains of metamorphic rock in much the same manner that the sea joins a rugged and deeply indented coast. The lava entered the valleys and gave them level floors of basalt; the deeply sculptured ridges between the valleys were transformed into capes and headlands; outstanding mountain peaks became islands in the sea of molten rock.

After the last of the lava sheets was spread out, the rivers flowing from the mountains began the excavation of channels across the basaltic plateau and have deeply dissected it. The most important of these channels is the one cut by Snake river. From the mouth of Snake river to Lewiston, the stream is in a comparatively narrow steep-sided canyon about 2000 feet deep. Where Snake river forms the boundary between Washington and Idaho, its gorge is about 4000 feet deep and 15 miles broad. Within this vast gorge there are many lateral ridges, and a great variety of topographic forms due to erosion. This portion of Snake river canyon compares favorably with even the most magnificent parts of the Grand Canyon of the Colorado, except that it lacks the gorgeous coloring to which so much of the charm of its southern rival is due.

The thickness of horizontally-bedded basalt exposed in the walls of Snake river canyon and in the adjacent Blue mountains, is in the neighborhood of 5000 feet, but the maximum thickness is not revealed. In the walls of the canyon at three localities the summits of steep, angular mountain ranges are exposed; one of these buried peaks rises about 2500 feet above the river and is covered by fully 1500 feet of horizontally-bedded basalt.

The sheets of clay, sand and gravel interleaved with the basalt, especially near its junction with the bordering mountains, furnish conditions favorable for obtaining artesian water. A number of flowing wells derive their water supply from this source.

The Blue mountains, at least at their northern extremity, consist of a broad, low, flat-topped dome of basalt which has been deeply dissected by consequent streams. The layers of basalt in the uplifted region are still horizontal except about its borders, where gentle outward dips occur.

The surface of the basaltic plateau is covered with residual soil, which has an average depth of 60 to 80 feet over thousands of square miles. The soil is exceedingly fine, dark brown or black in color and of wonderful fertility. This is the soil of the celebrated wheat lands. The sub-soil is fine, light yellowish in color, without stratification, and in many localities traversed by minute, irregular, but in general vertical tubes. In many ways this sub-soil resembles loess. Its origin from the disintegration and decay of the underlying basalt is clearly manifest.

Topographically the lava-covered region presents great diversity. In the Blue mountains there is an intricate series of sharp-crested ridges separated by a labyrinth of canyons, having in general a depth of about 3000 feet. Between the Blue mountains and Snake river on the north there are broad remnants of the nearly level plateau separated by narrow steep-sided canyons, in general 2000 feet deep. North of Snake river there is a vast area without deep canyons, but diversified by short hills, from 50 to 80 feet high, none of which, however, rise above a certain general level. Along the eastern portion of this hilly plateau or rolling prairie, as it was before cultivation began, there are a few prominent island-like buttes of quartzite, which rise through the basalt.

Among the details noted in the Columbia lava are certain horizontal joints which cut the vertical columns of basalt and in some cases may be traced for several miles. The large vertical columns of lava when weathered, occasionally show that they are composed of small horizontal columns or prisms, which radiate from a confusedly jointed, central core. The joints which bound the large vertical columns furnished the cooling surfaces for the rocks they enclose. The bases or ends of the radiating columns are frequently revealed on the surfaces of the slightly weathered vertical columns by a net-work of lines resembling shrinkage cracks.

A report on the observations outlined above will be published by the U. S. Geological Survey.

2. *Geologic Atlas of the United States Yellowstone National Park, Folio, No. 30, U. S. Geol. Surv., 1896.*—It seems safe to say that probably no other one of the atlas sheets issued by the Geological Survey will command more attention than this. The National Park has become so widely known and its marvels are so directly conducive to geological inquiry, that anything of a nature to be useful to the general public as well as to scientific men will certainly be appropriated with eagerness, and soon put to practical use.

The present atlas contains a topographic map of the park on the scale of 1:125,000, i. e. two miles to an inch, in four sheets. The triangulation and topography of these maps is by J. H. Renshawe, H. S. Chase, F. Tweedy, W. H. Leffingwell, and S. A. Aplin, Jr.

The geological maps are also four in number, corresponding to the topographic maps above. The geology is by ARNOLD HAGUE, J. P. IDDINGS and W. H. WEED, the former being in charge of

the work. Five pages of text written by Mr. Hague accompany the maps, giving a clear and admirable résumé of the geological history of the Park; there is an additional page by Mr. Iddings on the igneous rocks which play so important a rôle in the geology of the district. There are also three pages devoted to the reproduction of photographs of a striking character illustrating different objects of geological interest.

The economic maps of the general atlas sheets are of course wanting. The work is a superb example of the engraver's and printer's art.

Now that this interesting work has been issued, the advent of the special report on the geology of the district will be eagerly looked for and we trust that it may not be long delayed.

L. V. P.

3. *Report of the Director of the United States Geological Survey for the year 1895-96*; by CHARLES D. WALCOTT, Director. (Extract from 17th Ann. Rept. U. S. G. S., Part I), pp. 1-200. 1896.—In addition to the usual report of the detailed work of the Survey the director calls attention to the law passed by Congress, June 11, 1896, providing for the monumenting of the topographic surveys. The provision is embodied in the following clause in the sundry civil appropriation act of above date:

"*Provided*, That hereafter in such surveys west of the ninety-fifth meridian elevations above a base level located in each area under survey shall be determined and marked on the ground by iron or stone posts or permanent bench marks, at least two such posts or bench marks to be established in each township or equivalent area, except in the forest-clad and mountain areas, where at least one shall be established, and these shall be placed, whenever practicable, near the township corners of the public-land surveys; and in the areas east of the ninety-fifth meridian at least one such post or bench mark shall be similarly established in each area equivalent to the area of a township of the public-land surveys."

This provision, passed at the instigation of the Director, will greatly increase the value of the geologic survey work, both to geologists and to inhabitants of the territory surveyed.

The geologic work was carried on by twenty-eight field parties, the paleontologic work by six field parties. In the division of hydrography, field operations, under the general charge of Fred. H. Newell, were carried on in various regions of the United States, classified as humid, sub-humid and arid. A large list of rivers were systematically measured, classified under sixteen great river basins. The topographic branch of the survey during the year was reorganized, the classification into four sections being retained in charge of the same chiefs as heretofore, but the director assumed the immediate charge of the whole. There were forty topographic parties working in twenty-five different states and territories connected with this important branch of the survey, and 48,066 square miles were surveyed during the year.

In the editorial division 12,875 manuscript pages and 4627

printed pages were edited, and twelve geologic folios were published.

The library of the survey, which is becoming remarkably complete, has reached the total number, of books, pamphlets and maps, of 127,285. The appropriation for the fiscal year 1895-96 was \$521,890.

H. S. W.

4. *Geology of the Castle Mountain Mining district, Montana*; by W. H. WEED and L. V. PIRSSON. Bull. No. 139, U. S. G. S., pp. 1-164, pl. i-xvii, figs. 1-11, 1896.—This memoir is a general description of the geological features mapped on the Little Belt Mountains sheet, based upon field work done by the authors during the years 1892 and 1893, containing detailed account of the sections of the Algonkian, Cambrian, Carboniferous, Cretaceous and Miocene beds with reference to Silurian, Devonian and Juratrias outcrops, together with lists of fossils when obtained. The igneous rocks are described with fuller details, both petrographic and chemical, and chapter ix is devoted to study of the glacial phenomena of the region. Chapters x and xi give a summary of the economic and mineral products of the region.

H. S. W.

5. *The Eocene deposits of the Middle Atlantic Slope in Delaware, Maryland, and Virginia*; by W. B. CLARK. Bull. No. 141, U. S. Geol. Surv., pp. 1-167, pl. i-xl, 1896.—In this Bulletin is brought together a thorough account of the Eocene deposits of this region and their faunas based upon original investigations. Many new species are given, which with the known species are fully illustrated. The conclusions reached are given in a paper in this Journal.* An excellent brief synopsis of the criteria employed in the correlation of sedimentary rocks is given on pages 47 to 58.

H. S. W.

6. *Catalogue des Bibliographies Géologiques rédigé avec le concours des membres de la Commission bibliographique du Congrès par EMM. DE MARGERIE*. Congrès Géologique International 5me Session, Washington, 1891, 6me Session Zürich, 1894, 733 pp., Paris, 1896 (Gauthier Villars et Fils).—This exhaustive bibliography of bibliographies of geological works, containing 3918 entries, is the first published result of the international committee on geological bibliography organized at the Washington meeting of the *Congrès géologique international* in 1891.

The commission was entrusted with the threefold task of 1st, preparing a list of existing bibliographies of geology, whether separate works, lists in connection with special treatises or reports, or private lists or card catalogues, so far as known, in all countries and languages; 2d, provoking societies and geological surveys, operating in countries in which such lists have not been prepared, to prepare detailed catalogues of the works relating to the geology of their respective territories; and 3d, preparing for the periodic (annual if practicable) publication of the current bibliography, to be published immediately after the close of the period covered. The first of these tasks is accomplished in the present

* This Journal, IV, vol. i, pp. 365-374.

work; and all working geologists owe a deep debt of gratitude to the committee and, particularly, to the secretary, M. de Margerie, for the admirable results of their labors.

The arrangement and classification of the material is such as to make the work most useful. The plan of the work is as follows: The first classification of the matter is into a general and a regional part. The first part contains A. Histories and Bibliographies of general geology, B. Periodic bibliographies, C. Personal bibliographies, D. Bibliographies by subjects, E. Geographic geology in general. The second part, regional, contains separate lists for each separate European state (or group of states in a few cases), and each important country or group of countries outside Europe. Under each of these regional groups, the lists are classified under the following heads: 1, generalities, 2, catalogues of publications of official geological surveys, 3, general tables of the contents (periodic) of society and academy publications, 4, periodic bibliographies, 5, catalogues of booksellers, 6, personal bibliographies, 7, bibliographies arranged by subjects, 8, regional and local bibliographies.

Full titles are given throughout the work, and, in a large number of entries, brief notes indicate the special field covered by the volume or reference cited. The particular pages in which the bibliographic matter is found is also indicated in detail, a feature which will be appreciated by the busy student.

The committee is composed of fourteen members, each a prominent, active geologist of the country he represents, thus ensuring thorough and accurate work. We congratulate the indefatigable secretary, M. de Margerie, upon the completion of this work, which will be appreciated most highly by those who know something of the great labor involved in preparing it.* H. S. W.

7. *The Yellow Limestone of Jamaica*; by R. T. HILL (from a letter to Prof. A. Agassiz, dated Kingston, Feb. 2d).—My enforced stay at Kingston has resulted in the discovery that nearly all the so-called "Yellow Limestone" formations of Sawkins are *Cretaceous*. I have collected fossils in them at many localities; including Rudistes from the very top series at Catadupa and in the province of Clarendon.

8. *Handbuch der Mineralogie* von Dr. C. HINTZE. Neunte bis zwölfte Lieferung. Leipzig, 1897 (Veit & Co.)—Mineralogists in all lands will congratulate Dr. Hintze, and themselves as well, on the completion of volume ii of his monumental work on Mineralogy—the most exhaustive treatise ever attempted. The parts now issued embrace pages 1281 to 1842 and include, besides some other species, the feldspars, scapolites, and zeolites. A considerable time has elapsed since the appearance of the preceding eighth part, but workers in mineralogy will be reconciled for this in receiving at once the four parts here alluded to; moreover, they will now look forward with confidence to the completion of the whole work. The thoroughness and accuracy, which characterize Dr. Hintze's labors as an author, are too well known to need to be enlarged upon.

* We are informed that copies of this work may be obtained for \$5, from Mr. G. K. Gilbert, U. S. Geol. Survey, Washington; the Comptes Rendus of the Washington Congress will be sent to purchasers by Mr. S. F. Emmons.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Annals of the Astronomical Observatory of Harvard College*.—Part 4 of volume xxx and Part 5, vol. xl, recently received, contains the results of observations made at the Blue Hill Meteorological Observatory, Mass. The former volume is devoted to a paper by H. Helm Clayton on the discussion of cloud observations. It opens with an historical sketch of cloud nomenclature, which is followed by a statement of the new system founded upon the international nomenclature. The relations of clouds to rain-fall, cyclones, movements of the wind, and many other points, are discussed in detail, with other related subjects. The memoir is accompanied by seventeen plates, showing particularly the relation of the cloudiness in general, and the different forms of clouds, to the movements of cyclones and anti-cyclones.

Circular, No. 15, by E. C. Pickering, discusses the remarkable results obtained in photographing the stars by the Bruce photographic telescope and the subject is illustrated by some beautiful plates. Circular, No. 16, gives measurements of the spectrum of ζ Pupis.

2. *Smithsonian Physical Tables*; prepared by THOMAS GRAY. pp. xxxiv and 304. Washington, 1896. (Smithsonian Miscellaneous Collections, 1038.)—This volume forms the third part of the new series of Smithsonian tables planned by the Secretary, Prof. S. P. Langley. The first volume, which was issued in 1883 (see this Journal, xlii, 160), comprised the meteorological tables; the second, issued in 1894 (xlix, 327), included the geographical tables, and was prepared by Prof. R. S. Woodward. This third part includes the physical tables and has been prepared by Prof. Thomas Gray, of Terre Haute, Indiana. The introduction is given up to units of measurement and conversion formulæ, and then follow 315 tables relating to all the different departments of physics, but so varied in character that it is impossible to mention them individually. The value of so large and so carefully compiled a series of tables of physical constants is obvious and need not to be insisted upon.

3. *North Carolina and its Resources*. Issued by the State Board of Agriculture. 413 pp. with a map and numerous illustrations. Raleigh, 1896.—This handsome volume discusses the resources of North Carolina in all their varied aspects, economic and scientific. It thus contains much matter both of local and general interest. A large number of excellent plates show features of the scenery, agricultural industries, public buildings, etc., and add much to the attractive character of the volume.

4. *The National Museum*.—By the action of the Board of Regents of the Smithsonian Institution at its last annual meeting, Chas. D. Walcott, Director of the U. S. Geological Survey, was appointed Acting Assistant Secretary, with the understanding that his duties would be exclusively confined to the charge of the Museum, and that the appointment be considered as temporary until a permanent successor to the late G. Brown Goode shall be appointed.

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WITH PLATE VI.

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We have lately received a collection purchased for us in New South Wales, that is wonderfully rich in the splendid crystallizations of lead and silver minerals of the Broken Hill mines. The occasional samples that have found their way to Europe have given the locality a name for "fine things," though unfortunately so rare that they have reached but few collectors.

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXIV. — *An experimental investigation of the equilibrium of the forces acting in the flotation of disks and rings of metal: leading to measures of surface tension;*
by ALFRED M. MAYER.

It occurred to me that if a ring of metal with a chemically clean surface could be floated, and then gradually weighted till it broke through the surface of the liquid, one might thus directly measure surface tension. At the time I saw little prospect of succeeding in floating a ring with a clean surface, for all the treatises on physics I had read state that to float a metal on water its surface must be coated with a film of grease. A ring of aluminum seemed the more likely to float because this metal has a peculiar repellent action on melted alloys, like ordinary solders. I made a ring of aluminum 50^{mm} in diameter out of wire 1^{mm} thick. It floated on water. As I gradually added weight to the ring (see fig. 4) it sank deeper and deeper in a depression in the water, till having reached a depth of 5^{mm}, it broke through the water-surface. The total weight required to make the ring break through the surface was 2.6 grams.

In subsequent experiments I floated a ring of 61.8^{mm} in diameter made of aluminum rod 3.7^{mm} ($\frac{1}{8}$ in.) in diameter. This ring weighed 5.8 grams. To float this ring requires a steady hand and patience; but a ring made of aluminum rod 3.15^{mm} ($\frac{1}{8}$ in.) in diameter is easily floated. With this ring may be made an interesting experiment. The ring with fine wire yoke and cup (see fig. 4), weighs 4.435 grams. One gram added to the ring causes it to sink, giving 5.435 as the breaking weight. The unloaded ring therefore weighs 19 per cent

less than the breaking weight. If from any cause, such as the gathering of dust on the water, or, the contamination of its surface from the vessel holding it, the surface tension should be weakened 19 per cent, then the unloaded ring will sink. This weakening of the surface tension is readily and rapidly brought about by pouring vapor of ether on the water. When this vapor reaches the water the ring moves to and fro in a tremulous manner and then sinks.

In my ignorance, I saw in these experiments a property of flotation peculiar to aluminum. Experiment, however, soon showed me that all metals, with clean surfaces, from platinum of a density of 21.5 to magnesium of a density of 1.7, float on water. When and with whom originated the erroneous statement, that metals to float must have their surfaces greased, I have not been able to discover; but this error has been copied from one treatise on physics into another for about a century. The older writers, and those who in recent times have published papers on their studies of these phenomena, make no mention of the necessity of greasing a metal to make it float.

In his "History of Physics"* Poggendorff states that "Norman (he who discovered the dip of the needle) showed Gilbert that a needle placed carefully on water floats, and if magnetized points constantly in one direction." Poggendorff does not give his authority for this statement. Gilbert in his "De Magnete," 1600, does not say that Norman floated a metal *per se* on water. He thus describes Norman's experiment: "Norman proves his theory as follows: Take a round vessel full of water; on the mid surface of the water float a small bit of iron wire supported by just as much cork as will keep it afloat while the water is in equilibrium: the wire must have been first magnetized so as to show plainly the variation point D. . ."† It may be that Norman's experiment of floating a needle is described in his "New Attractive," 1596, a very rare work, which I have not been able to consult.

"The observation of Norman, that a steel needle placed carefully on water floats, led Borelli, 1655, to study more minutely this phenomenon. He procured two little sheets of brass, and placed them with care on water, where they floated. By means of rods he pushed them towards one another, and saw that when they had approached sufficiently, they mutually attracted."‡

Descartes in "Les Météores," Leyden, 1638, says:§ "La superficie de l'eau est beaucoup plus malaysée a diuiser que

* Histoire de la Physique, Paris, 1883, p. 170.

† "De Magnete." Translation by P. Fleury Mottelay, p. 244. N. Y., 1893.

‡ Poggendorff: Hist. de la Phys., p. 249.

§ I give this quotation in the orthography of his time.

n'est le dedans, ainsi qu'on void par expérience en ce que tous les corps assez petits, quoyque de matière fort pesante, comme sont de petites aiguilles d'acier, peuvent flotter et estre au-dessus, lorsequ'elle n'est point encore diuisée, au lieu que lorsqu'elle l'est ils descendent iusque fonds sans s'arrester."

The next paper on the subject is by "M. Petit le Médecin," published in the Memoirs of the Academy of Sciences, Paris, 1731, in which the author states that the reason why a metal floats on water is that it is kept from touching the water by a film of air which coats the surfaces of all metals. I think that M. Petit makes good his statement, for he shows that on heating a metal it no longer floats, but sinks. He makes no mention of having previously greased the wires and sheets of metal with which he experimented.

Rumford, in 1807, published a paper in the Memoirs of the Academy of Sciences, of Paris, in which he attempts to show that a film of air does not exist on floating metals. I do not think that he makes good his opinion, for the only experiments he makes to sustain it are those in which water is covered with ether, with turpentine, or with olive oil, and small spheres of tin and of mercury, allowed to fall through the supernatant liquid, are retained by the surface of the water, which takes the form of sacs, that support and partly inclose the spheres.

In 1824 Pichard,* engineer in the French army, thus explains the floating of a needle. If the needle be not wetted then it sinks in a depression of the surface of the water, and the vacant space caused by this depression together with the needle forms a float. When the specific gravity of this, as a whole, is less than that of the liquid, its weight will be insufficient to overbalance the upward hydrostatic pressure of the liquid, and it will float upon the surface of the latter. He then refers to the existence of an elastic pellicle, as held by some, and to that of the adherent layer of air as held by others, but does not adopt either, or propose any explanation of his own other than that of the compound float formed by the needle and the empty space around it from which the water has been displaced.

Gaillieron,† in a letter to De la Rive, after referring to the opinion of some physicists that a film of air adhering to the floating body is the cause of the depression made by it in the surface of the liquid, says: "This explanation is hypothetical, not even reaching a high degree of probability. It is therefore permissible to advocate another explanation, that of Count Rumford, defining once for all what is understood by pellicle."

* *Considérations sur les phénomènes que présentent de petites aiguilles à coudre, posées doucement et dans une situation horizontale, sur la surface d'une eau tranquille.* Biblioth. Univ., t. xxv, p. 273.

† *Sur les mouvements de certains corps flottants sur l'eau.* Bibl. Univ., vol. xxvi, p. 190, 1824.

But his definition is faulty. It is simply that a molecule of water at the lowest part of the floating body draws the neighboring molecule with it, this a third and so on. "The cohesion which unites all the molecules of the surface of the water forms a kind of pellicle, and there results a sac at the bottom of which the heavy solid rests."

In a second paper Gaillieron* gives an account of further experiments. He places a layer of oil upon the water, and drops the needle gently into it. It descends to the surface of the water. On looking upward at it through the glass, one sees, not the surface of the needle, but only the surface of the oil depressed by it. He explains these experiments by means of the existence of a pellicle.

De Maistre† (1841), after describing the floating of metals on the surface of water, says: This remarkable phenomenon is due to the fact that the molecules which form the surface of water have a force of mutual attraction greater than in the interior of the liquid. He then goes on to deduce the radius of activity of the molecular forces by studying the case of a drop of water formed at the end of a glass rod. The largest drop he could obtain had a radius of $1\frac{1}{4}$ line, and he supposes the size of the drop to be determined by the molecular attraction, which he therefore regards as acting effectively up to a distance of $1\frac{1}{4}$ line. At the close of his paper he quotes Rumford as having occupied himself with the peculiar properties of the surface of a liquid, and as having explained them by the supposition of a pellicle, the existence of which he considers to be proved.‡

"M. Artur, in his *Théorie élémentaire de la Capillarité*, Paris, 1842, is led from theoretic considerations to regard the superficial layer of all liquids as having a greater density and greater cohesion than exist in the interior, and therefore as having a certain resistance. Considering only the laws of hydrostatics, the volume of the depression formed in the surface of water by a floating needle should exceed by six times the volume of the needle, the density of steel being 7·8; but M. Artur and others have estimated the volume of this depression, and the highest valuation of it gives only three times the volume of the needle."§

In 1869 M. Leboucher|| appears as the first physicist to study

* Bibl. Univ., vol. xxvii, p. 207, 1824.

† Notice sur la cause qui fait surnager une aiguille d'acier sur la surface de l'eau. Bibl. Univ., vol. xxxv, p. 192, 1841.

‡ The foregoing extracts from the Bibl. Univ. were given me by Prof. Arthur W. Wright.

§ Taken from Plateau's "Statique expérimentale et théorique des liquides." 1873, vol. 2, p. 79.

|| "Recherches expérimentales et théoriques sur un cas particulier de la théorie des corps flottants." Caen, Mem. Soc. Linn. de Normandie, XV, 1869, No. 2.

seriously the interesting phenomena presented in the flotation of metals. He is the first to make quantitative experiments. I have not been able to consult the volume in which his research appeared and all I have of his work is the abstract of it given by Daguin in his *Traité de Physique*, 1878, vol. 1, p. 277.

Leboucher floated on water thin plates of various substances and then loaded these gradually till they broke through the surface of the water. He then computes, e , the thickness a plate must have so that it will just *not* float. Knowing W , the total weight required to make the plate sink; d , the density of the substance, and s , the area of the plate, we have $W = s e d$. The value of e found for slate, mica, and brass is respectively 1.5^{mm} , 1^{mm} , and 0.5^{mm} .

To ascertain the upward hydrostatic pressure on the plate he measured the depth, h , of the bottom of the loaded plate below the general level of the water by means of a spherometer, the screw of which was brought in contact with the surface of the water and then with the surface of the plate. The spherometer rested on a horizontal annulus of glass placed on the rim of the vessel holding the water. Adding e to the depth measured we have h , and the upward pressure on the plate $= s h \times \text{density of water}$.

Leboucher does not arrive at an equation of the forces acting on the floating plate, but states that the upward hydrostatic pressure on the plate is a little less than the weight of the plate; the difference is generally $\frac{1}{10}$ to $\frac{1}{5}$ of the weight of the latter; which he explains by the supposed existence of a capillary tension on the lower edge of the plate which is always slightly rounded. This tension acts with the upward hydrostatic pressure in balancing the weight of the plate. I shall recur to this opinion of M. Leboucher.

Equation of the forces acting in the flotation of a disk of metal.

Three forces are acting on a floating disk of metal (1) W = the weight of the disk; (2) P = the upward hydrostatic pressure on the bottom of the disk; (3) T = the vertical resultant of the surface tension of the water along the circumference of the upper edge of the disk. The relation of these forces is given by the simple formula

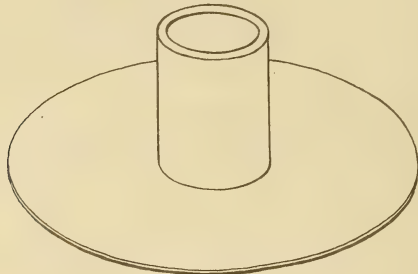
$$W = P + T$$

We can measure W and P , and $T = W - P$. Let circ = the circumference of the disk, then $A = \frac{T}{\text{circ}} \div \cos. \text{angle of vertical with the depressed water surface at upper edge of disk}$; A

being the capillary constant, or surface-tension in grams per centimeter.

W is taken as the weight of the disk and superadded weight required to make the disk break through the water-surface. $P = a h d$, where a is the area of disk; h , the depth to which the bottom of the disk has sunk below the general level of the water at the moment it breaks through the water-surface, and d , the density of the water.

Fig. 1.



The manner of measuring W is as follows: A disk, fig. 1, has a hollow cylinder soldered or cemented to it. This cylinder is concentric with the circumference of the disk. The disk is floated on freshly distilled, clean water contained in a glass vessel, and the under surface of the disk is examined to be sure that no bubbles of air are adhering to it. Fine wind-blown sand, contained in a bottle provided with a bent tube of glass having a small aperture, is poured into the cylinder till the weight causes the disk to sink. The water has such a depth that when the disk has sunk the surface of the water is several millimeters below the top of the cylinder. The disk is now wiped dry and weighed. The water just used is rejected, replaced by clean water and the experiment repeated. The water is contained in a shallow cylindrical glass vessel, 16.5^{cm} in diameter. The edge of this has been ground flat so that the vessel may be closed by a glass plate and the water protected from dust till the moment when the disk is floated on it. The time which elapses from the moment the disk is floated till the load of sand causes it to sink averages 25 seconds.

The disks experimented on were made of aluminum. They were 1^{mm} thick and of various diameters. They were flat, and the cylindrical surface of the disk was quite smooth and polished. To accomplish this one must have a keen turning tool, and in turning the aluminum, it and the tool must be constantly supplied with petroleum. When finished the disks were cleaned

by first rubbing them with ether contained in a soft clean rag. The ether was then removed with absolute alcohol, and the latter with distilled water. The disk then remained under cover for an hour or more before experiments were made with it.

The depth, h , to which a disk went in the depressed water before it broke through its surface was measured as follows: A brass rod was turned so that it fitted neatly into the cylinder on the disk. This rod was attached to a slide moved by a micrometer screw in a vertical direction. The surface of the disk was carefully levelled. The disk was then screwed down till it just touched the surface of the water. That the plane of the under surface of the disk coincides with the plane of the water is known by examining the lower surface of the disk, when it will be found that if the plane of the disk is just in the plane of the water there is a uniform illumination over the surface of the water, but if the surface of the disk is the least below or above the surface of the water then the disk will be surrounded with a bright border. The disk is now lowered by the micrometer screw till it breaks through the water-surface. The instant that this happens is not as sharply marked as when the disk, free to move downwards, breaks through the surface from its weight, because the first intimation we have of the disk having reached the depth when rupture of the depressed surface takes place is that the latter begins to leave the sharp edge of the disk and to flow inwards over its surface. Hence h cannot be measured so accurately as W . This is shown in the tables of experiments on disk No. 1.

The measure of h given in the tables are the real depths to which the disk has sunk below the level of the water at the moment of rupture. It is evident that as the disk is depressed beneath the surface, the general level of the water in the vessel rises, and that the larger the diameter of the vessel the less the rise of the water, and consequently the less the error likely to be made in the computation. The vessel used in these experiments has a diameter of 16.5^{cm}. By adding to the depression of the disk, as measured by the micrometer screw, the computed rise of the water in the vessel we obtain h .

The reason why we take W and h at the moment when the disk breaks through the surface of the water is that these quantities can be more accurately measured at the moment of rupture of the surface, and also at this moment W corresponds accurately with h .

Experiments on Disk No. 1. Temp. 18°.

| | |
|------------------------|--------------------|
| Diameter of disk..... | 5.09 ^{cm} |
| Thickness of disk..... | 0.1 ^{cm} |

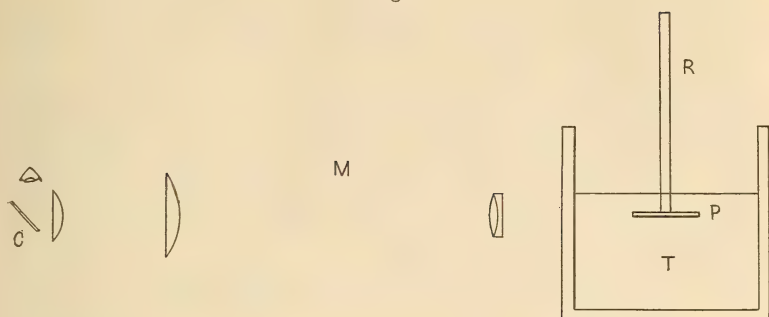
| | W | h |
|----|----------------|-------------------|
| 1) | 11.327 grams. | 0.502 centimeter. |
| | | .483 |
| 2) | .272 | .507 |
| | | .489 |
| 3) | .333 | .507 max. |
| | | .500 |
| 4) | .335 | .497 |
| | | .500 |
| 5) | .185 min. | .481 min. |
| | | .505 |
| 6) | .287 | .500 |
| | | .506 |
| 7) | .380 | .500 |
| | | .489 |
| 8) | .276 | .498 |
| | | ----- |
| 9) | .425 max. | 0.497 = mean. |
| | ----- | |
| | 11.313 = mean. | |

In the experiments on W the mean of the difference of the maximum and minimum measures from the mean is .12, and $\frac{.12}{11.318} = \frac{1}{94}$; while in the measures of *h* we have the mean of the difference of the maximum and minimum measures from the mean equal to .013, and $\frac{.013}{.497} = \frac{1}{38}$. The knowledge of the upward hydrostatic pressure on the disk, so important in the deduction of the value of the tension from the equation $W = P + T$, seems to be uncertain, and it is not to be expected that experiments with disks can give accurate value of *T*.

On the form of the depressed water-surface.

To compute the tension in the plane tangential to the water-surface, along the circumference of the upper edge of the disk, it is necessary to know the angle that the depressed water, along this edge, forms with a vertical to this edge. The contour of the depressed surface was obtained in the following manner. A rod, R, fig. 2, was fastened at right angles to the plane of a square plate, P, of aluminum 0.1^{cm} thick. This rod

Fig. 2.



was fastened to the slide and micrometer screw used in determining h , and the plate of aluminum was brought down to the surface of the water contained in a tank, T, having sides of flat glass. The number of turns of the micrometer screw to bring the plate P to the depth of rupture of the water was ascertained. Then it was easy to depress the square plate in the water till it was just on the point of rupture. While in this position the edge of the plate was viewed in the microscope, M, provided with a camera lucida, C, and a drawing was made of the contour of the depressed water-surface. It is true that there must be some distortion of this contour, caused by refraction of the depressed water, but it is the only way by which I have been able to obtain even an approximation to the contour. The microscope objective, called a 3-inch, was of large aperture and of the low magnifying power of $11\frac{1}{4}$ diameters.

Fig. 3.



Fig. 3 is the average of several drawings of the contour. The engraving shows the disk, the depressed water and the contour of the latter, magnified $7\frac{1}{2}$ diameters. If the depressed surface met the edge of the disk normally, then the center of the radius of curvature of the lowest portion s , of the surface

would be at R, in the horizontal plane of the disk; but it was found to be at R', so that R s R' equalled 6°, thus giving 6° for the angle at s of the water-surface with a vertical to that point. Call this angle d .

We are now in possession of the facts pertaining to the forces acting on the floating disk. W and P are known and $T=W-P$. If the equation $W=P+T$ be correct, then $\frac{T}{\text{circ}} \div \cos \alpha$ should equal, or approximate, the value of A, the capillary constant, or, the surface-tension.

Data relating to disk No. 1, and value obtained for A.

| | |
|---|-------------------------|
| Diameter of disk | 5.09 ^{cm} |
| Thickness of disk | .1 ^{cm} |
| Circumference of disk | 15.99 ^{cm} |
| Area of disk | 20.348 ^{sq cm} |
| Density of water at 18° | .9986 |
| W | 11.313 ^{grhms} |
| h | .497 |
| $P=ahd=20.348 \times .497 \times .9986=10.092$ | |
| $A=\frac{W-P}{\text{circ}} \div \cos 6^\circ = \frac{11.313-10.092}{15.99} \div .9945=.07678$ | |

For disks No. 2 and No. 3 W and h were determined by series of measures similar to those made on disk No. 1. The departure of the minimum and maximum measures from the mean was about the same as obtained in the measures on disk No. 1.

Data relating to disk No. 2, and value obtained for A.

| | |
|---|-------------------------|
| Diameter of disk | 4.975 ^{cm} |
| Thickness of disk | .1 ^{cm} |
| Circumference of disk | 15.63 |
| Area of disk | 19.438 ^{sq cm} |
| Density of water at 18° | .9986 |
| W | 10.885 ^{gram} |
| h | .495 ^{cm} |
| $P=ahd=19.438 \times .495 \times .9986=9.608$ | |
| $A=\frac{W-P}{\text{circ}} \div \cos 6^\circ = \frac{10.885-9.608}{15.63} \div .9945=.08215.$ | |

Data relating to disk No. 3, and value obtained for A.

| | |
|--|------------------------|
| Diameter of disk | 5.571 ^{cm} |
| Thickness of disk | .1 ^{cm} |
| Circumstance of disk | 17.5 ^{cms} |
| Area of disk | 24.38 ^{sq cm} |
| Density of water at 18° | .9986 |
| W | 13.739 |
| h | .508 |
| $P=a \times h \times d=24.38 \times .508 \times .9986=12.368$ | |
| $A=\frac{W-P}{\text{circ}} \div \cos 6^\circ = \frac{13.739-12.368}{17.5} \div .9945=.07877$ | |

The values of A given by the experiments on the three disks are $\cdot0767$, $\cdot0821$, $\cdot0787$. The mean value is $\cdot0791$. The mean value of 28 determinations of A is $\cdot0772$. The value of A found from the experiments on the disks is so close to this value (only $2\frac{4}{10}$ per cent higher), that the formula $W=P+T$ seems to be the correct expression for the equation of the forces concerned in the flotation of a disk. However, I do not think that experiments on floating disks are of value in determining A , for the determination of the value of h , and consequently of P , is too uncertain. The maximum value of A obtained from the experiments on the disks is 7 per cent higher than the minimum and even this degree of concordance I regard as accidental.

It is seen that I do not agree with M. Leboucher in locating the upward action of the surface tension of the water along the *lower* edge of the disk, where M. Leboucher evidently regards the water as having a free surface; which it has not, as I shall subsequently show. I locate it on the free curved surface of the water above the upper edge of the disk.

If this upward pressure on the disk should be produced as M. Leboucher supposes, then this pressure will be nearly independent of the radius of curvature of the lower edge of the disk, for the area of this curved surface will vary as its radius while the capillary pressure will vary inversely as its radius. The capillary pressure $P=A\left(\frac{1}{R}+\frac{1}{R'}\right)$; where R is the radius of the curved edge, which we suppose variable, while R' remains constant, varying very little from the radius of the disk; but $\frac{1}{R'}$ is so very small compared with $\frac{1}{R}$ that the value of P varies but little with various values of R .*

On the equation of the forces acting on a floating ring of metal, and on measures of surface tension obtained from experiments on floating rings made of various metals.

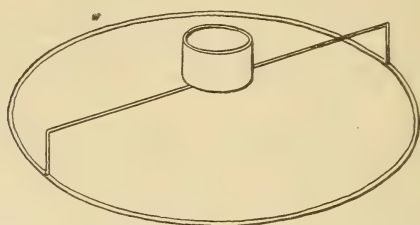
The floating ring presents more complicated, but more interesting phenomena, than those given by a floating disk. In the floating disk we have W and P quantities about ten times larger than T , and T is the vertical resultant of the tension acting along only one circumference; whereas in the case of the floating ring P is a small fraction, only $\frac{1}{14}$ or $\frac{1}{21}$, of W , and W is nearly equal to the vertical resultant of the surface-

* A drawing of the edge of disk No. 3 with a microscope and camera lucida gave $\frac{1}{20}$ mm for the radius of curvature of the edge. This makes $\frac{1}{R}=200$, while $\frac{1}{R'}$ is only 0.36.

tension along the lower borders of the two water-surfaces; one of these on the outer side, the other on the inner side of the axis of the ring. Thus while we cannot deduce a reliable measure of the surface tension from a knowledge of W and P in the case of the disk, we have conditions quite favorable to that measure in the case of the floating ring.

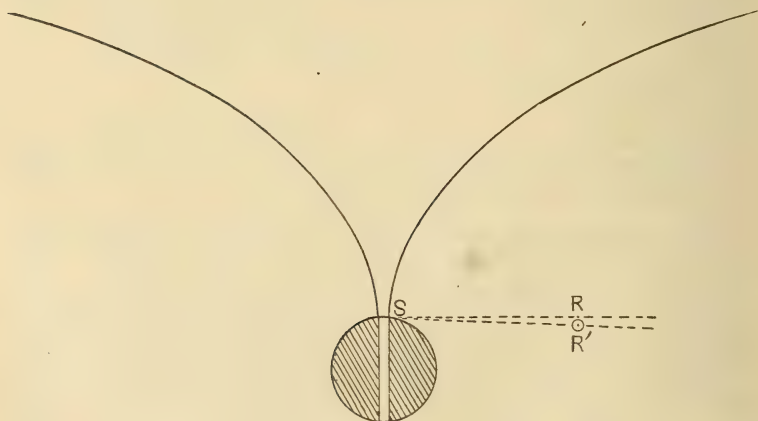
If a floating ring, fig. 4, formed of wire of 1^{mm} in diameter,

Fig. 4.



be gradually loaded by pouring fine sand into the cup carried by the ring, it sinks deeper and deeper into the depressed surface of the water till it has reached a depth of 0.503^{cm}, when it suddenly breaks through the surface and sinks.

Fig. 5.

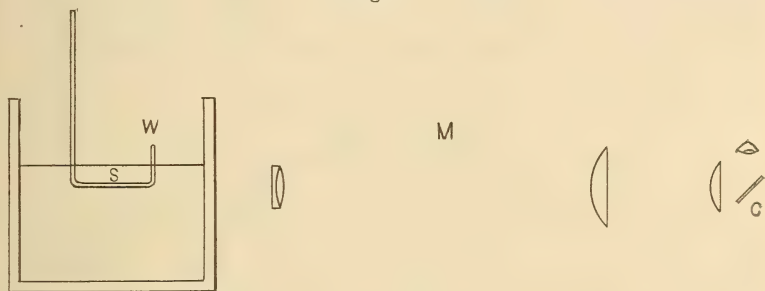


As the ring descends in the depression in the water, the latter incloses more and more of the ring till the opposite surfaces of the depression have approached to $\frac{1}{10}$ ^{mm} as shown in fig. 5,

and the wire appears hung in an annular envelope of water supported by the two curved water surfaces. As the wire descends in the water these water surfaces always meet the wire as surfaces convex upward. When the two water-surfaces have approached it $\frac{1}{10}$ mm as shown in fig. 5, the angle made by a water-surface with the vertical where it meets the wire at that point is $2\frac{1}{2}^\circ$.

The contour of the depressed surface of the water, as I have drawn it, was obtained as follows: In a tank, fig. 6, with sides

Fig. 6.



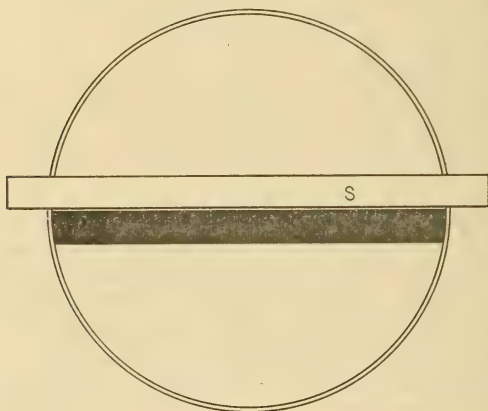
made of flat glass, a wire W, of 1 mm in diameter, bent twice at right angles, is brought down into the water by means of the slide and micrometer screw already described. It was found that this wire went to the same depth, .503 cm, before it broke through the depressed water as did a ring made of wire of the same diameter. A microscope, M, with a low-power objective, magnifying $11\frac{1}{4}$ diameters, is focussed on the wire at S. The leg, W, of the wire acts only as a kind of diaphragm to the objective and does not prevent one from having a sharp image of the depressed water-surface at S, though this point is directly behind the wire, W. Undoubtedly there must be some distortion in this image, caused by the refraction of the depressed meniscus of the water; but this method, used to obtain the approximately correct contour of the surfaces of the depression, is the only one I have been able to devise. With the camera lucida at C, several drawings were made of the contour of the surfaces. The one given in fig. 5 is formed by combining these drawings in an average curve.

The upper horizontal line shows the general level of the surface of the water. The bottom of the wire is .503 cm below this level. The figure represents the phenomenon magnified 14 diameters. On this scale the depressed surfaces would meet the general level of the water at 21 cm on either side of the centre of the figure. If the radius of curvature of the portion

of the water-surface near the wire were at R, in the horizontal plane through S, then the curved surface where it meets the wire at S would be tangent to a vertical at that point. But the radius of curvature of this portion of the curved surface is at R', making RSR' equal to $2\frac{1}{2}^\circ$ and showing that the vertical to S makes an angle of $2\frac{1}{2}^\circ$ with the tangent to the curve at that point.

To determine the lateral extent of the depression of the water on either side of the wire of 1^{mm} in diameter, when it is just on the point of breaking through the water, the following method was used: On the top of a cylindrical vessel, holding water to within about 3^{mm} of its top, was placed a millimeter scale, S, fig. 7, 8^{mm} wide. On the upper surface of this scale

Fig. 7.



was cemented a slip of thin mirror glass with its plane inclined to the horizontal scale S, as shown in fig. 8. The top of the glass vessel was carefully levelled so that its plane was parallel to that of the water. On looking at the scale with the line of sight at the proper angle of incidence we see the scale directly, and in front of it the image of its lower surface reflected from the water. The off edge of this dark reflected image of the scale is made nearly to coincide with the near edge of the scale, so that a narrow, bright line is seen between the off edge of the reflection and the near edge of the scale, as shown in fig. 7. On now depressing the wire in the water, the surface of the latter is curved, and this surface curves the reflection of the edge of the scale. By sighting along the scale so that the pupil of the eye is seen reflected from the slip of mirror, at the point where the curved

Fig. 8



reflected edge of the scale becomes straight and parallel to the edge of the scale itself, we determine the extent of the depressed water-surface on either side of the vertical passing through the axis of the wire. This depression of the surface was found to extend to 15^{mm} on either side of the wire, when the latter was so deep that it was just on the point of breaking through the surface. I measured the area of the vertical section of this depression below the horizontal surface of the water and found it to be about 25 times the area of the cross-section of the wire.

The weight on one centimeter of a ring, formed of wire 1^{mm} in diameter, when on the point of sinking, is .1696 gram, and the volume of one centimeter in length of the depression in the water, including the volume of the wire, if supposed to be formed of water, will weigh .2 grams, or 20 per cent more than the weight on one centimeter of the wire.

Evidently the two opposite surfaces of the depression in the water made by the ring cannot be similar, as is the case in fig. 5, showing the contour of the surfaces on either side of the straight wire, for the curvatures of the water-surfaces in the horizontal and vertical planes on the outer circumference of the ring are opposed to one another, while these curvatures on the inner circumference of the ring have the same sign. It follows that $P = A \left(\frac{1}{R} - \frac{1}{R^i} \right)$ gives the molecular pressure of the outer and lower border of the surface of the depression, and $P = A \left(\frac{1}{R} + \frac{1}{R^i} \right)$, the pressure of the lower border of the inner surface. Assuming these pressures equal to the hydrostatic pressure, the radius of curvature on the vertical plane of the inner surface will be to the radius of curvature in the vertical plane of the outer surface as 1 : 1.162, as is shown in fig. 9.

Rings of wire 1^{mm} in diameter were made of iron, tinned iron, copper, brass and of german silver. The average diameter of the axes of these rings is 5.35^{cm}. The weight on a centimeter of the circumference of the axis of a ring required to make the ring sink, averaged, for the five rings, .1696 gram.

Experiments on rings from 3 to 7.5 centimeters in diameter showed that, within these limits, the weight per centimeter of circumference required to sink the ring is constant, and therefore independent of the length of the circumference of the ring. The difference between the weight per centimeter required to sink the ring of 3^{cm} and the ring of 7.5^{cm}, as given by the experiments, amounted to only $\frac{1}{2}$ of one per cent.

Fig. 9.



We now come to the consideration of the upward hydrostatic pressure on a ring at the moment the weight on the ring is sufficient to cause it to break through the water-surface. Fig. 5 shows a vertical section of a straight wire and of the contour of the depressed water-surfaces at or near the moment when the ring breaks through the water, and fig. 9 shows the section of the wire of a ring and the contours of the depressed water-surfaces. I say at or near the moment when the ring breaks through the water because, though I have made scores of observations on the upper surface of the ring between the two opposed sheets of depressed water, with a microscope provided with a micrometer eye-piece, I have not been able to decide whether the surfaces of fig. 5 and fig. 9 break near the ring when the surfaces have approached to $\frac{1}{16}$ mm, as shown in the figures, or whether these surfaces, as shown in fig. 10, come

Fig. 10.



suddenly in contact the instant before the ring sinks. On some days I would rise from the microscope confident that the surfaces gave way before they came in contact; on other days I would be equally decided that they really met just as the ring went through the surface of the water. I am of the opinion that the latter condition is more likely to be true.

Evidently the upward hydrostatic pressure on the ring will differ in the two cases. Supposing that fig. 5 and fig. 9 give the real conditions at the moment of rupture of the water-film, then the upward hydrostatic pressure per centimeter on the ring equals the volume of one centimeter in length of the shaded portion of the section of the wire (see fig. 5), multiplied by .9989, the density of water at 16°. To this is added the upward hydrostatic pressure or the area of $\frac{1}{16}$ mm by 1 cm on the bottom of the wire. This equals $.01 \times .503 \times .9989$, making .01186 for the total upward pressure. But if the two opposed surfaces meet at the instant the ring sinks, as shown in fig. 10, we have for the upward hydrostatic pressure on one centimeter of the ring, .00785 cc, the volume of one centimeter of the wire, $\times .9989$, the density of water at 16°; this equals .00784 gram.

Determination of the surface tension of water from the experiments on the rings.

Let W = the weight required to make the ring break through the depressed water-surface; P = the upward hydrostatic pressure on the ring at the instant it breaks through the water; and T = the vertical resultant of the surface tension

along the lowest part of either of the depressed surfaces of water when these surfaces are nearly in contact, or in actual contact, and therefore when the circumferences of these surfaces may be regarded as equal to the circumference of the axis of the ring. Then,

$$W=2T+P.$$

If we divide W by the circumference of the axis of the ring in centimeters we obtain, as the average of 30 experiments, .1696 gram per centimeter. The upward hydrostatic pressure will be either .01186 or .00784 according as the two opposed films of water are as shown in fig. 9 or as in fig. 10.

If as in fig. 9, then $A = \frac{.1696 - .01186}{2} \div \cos 2\frac{1}{2}^\circ = .07895$. If

as in fig. 10, then $A = \frac{.1696 - .00784}{2} \div \cos 2\frac{1}{2}^\circ = .08095$.

A ring is formed by bending wire, 1^{mm} thick, around a cylinder or a cone, so that the axis of the ring shall be in a plane; in other words, so that the ring shall be flat. To obtain a flat ring is not easy, often only after several trials is it secured. Its ends are then neatly soldered together and the solder outside the juncture is carefully removed. Over a diameter of the ring is soldered a wire of $\frac{2}{16}$ ^{mm} thick, raised above the plane of the ring as shown in fig. 4. On the top of this wire, and concentric with the circumference of the ring, is soldered a cup made of thin ($\frac{1}{16}$ ^{mm}) brass. The ring is now polished, and cleaned by the successive use of ether, strong alcohol and distilled water. After it has remained several hours under cover it may be experimented with.

The weight required to force the ring through the surface of the water is obtained by pouring into the cup of the floating ring a fine stream of sand issuing from a small smooth aperture in a bent glass tube which goes through a cork in a bottle containing the sand. This sand is from Minnesota. It is wind-blown, the grains being globular, or ovoid. It was passed through a sieve having 100 meshes to the inch. It is hardly possible to stop the running of the sand into the cup at the moment the ring sinks. From several experiments I estimated that on the average about three milligrams of sand were poured into the cup after the ring had really broken through the water, and this quantity was subtracted from the breaking weight of each experiment. Fresh distilled water was used in each experiment. On the average, each experiment occupied twenty-five seconds.

The depth to which a ring has descended in the depressed surface of the water at the moment the ring sinks was determined as follows: A ring of 5.3^{cm} in diameter made of tinned

iron wire, 1^{mm} thick, was attached to the slide and micrometer screw already described in connection with the experiment on the disks. The following depths were measured. They are the depths given by the micrometer screw readings plus the computed elevation of the water in the vessel caused by the depression of the ring in the water-surface.

| | |
|-------|--------------------|
| 1) | ·507 ^{cm} |
| 2) | ·502 |
| 3) | ·503 |
| 4) | ·503 |
| 5) | ·500 |
| 6) | ·503 |
| <hr/> | |
| | ·503 = mean |

Experiments on the rings.

Let $\text{circ}' =$ the circumference of the axis of a ring; then $\frac{W}{\text{circ}'} = w =$ the breaking weight per centimeter of circumference of the ring. Let $p =$ the upward hydrostatic pressure on one centimeter of the ring. For p we take ·00784, supposing that the two opposite depressed surfaces of the water meet at the instant the ring sinks. Let $A =$ the surface tension of water in grams per centimeter.

Experiments on the ring of Iron.

| | | |
|--------------------------|-------|--------|
| Diameter of axis of ring | ----- | 5·455 |
| Circumference " " | ----- | 17·137 |
| Temp. of water | 16°. | |

W

2·866 min.

·891

·871

·886

·884

·894 max.

2·882 = mean.

$$\frac{W}{\text{circ}'} = \frac{2·882}{17·137} = ·16817 = w$$

$$A = \frac{w - p}{2} \div \cos 2\frac{1}{2} = \frac{·16817 - ·00784}{2} \div ·999048 = ·08023$$

Experiments on ring of tinned Iron.

Diameter of axis of ring 5.308
 Circumference " " 16.675
 Temp. of water 16°.

W
 2.817 min.
 .838
 .848 max.
 .830
 .841
 .820

2.832 = mean.

$$\frac{W}{\text{circ}} = \frac{2.832}{16.675} = .16982 = w$$

$$A = \frac{w-p}{2} \div \cos 2\frac{1}{2}^\circ = \frac{.16982 - .00784}{2} \div .999048 = .08107$$

Experiments on ring of Copper.

Diameter of axis of ring 5.46
 Circumference " " 17.153
 Temp. of water 16°.

W
 2.920
 .914
 .913 min.
 .928 max.
 .928
 .926

2.9215 = mean.

$$\frac{W}{\text{circ}} = \frac{2.9215}{17.153} = .17035 = w$$

$$A = \frac{w-p}{2} \div \cos 2\frac{1}{2}^\circ = \frac{.17035 - .00784}{2} \div .999048 = .08132$$

Experiments on Brass ring.

| | |
|--------------------------------|--------|
| Diameter of axis of ring | 5·183 |
| Circumference " " | 16·283 |
| Temp. of water 16°. | |

W

2·781 max.

·759 min.

·767

·765

·762

·761

 2·7658

$$\frac{W}{\text{circ}} = \frac{2·7658}{16·283} = ·16985 = w$$

$$A = \frac{w-p}{2} \div \cos 2\frac{1}{2}^\circ = \frac{·16985 - ·00784}{2} \div ·999048 = ·08107$$

Experiments on ring of German Silver.

| | |
|--------------------------------|--------|
| Diameter of axis of ring | 5·382 |
| Circumference " " | 16·908 |
| Temp. of water, 16°. | |

W

2·863

·895

·861

·901 max.

·863

·856 min.

 2·873 = mean.

$$\frac{W}{\text{circ}} = \frac{2·873}{16·908} = ·16992 = w$$

$$A = \frac{w-p}{2} \div \cos 2\frac{1}{2}^\circ = \frac{·16992 - ·00784}{2} \div ·999048 = ·08111$$

The tables of experiments on these five rings show that the average difference of the mean of the minimum and maximum measures from the mean equals $\frac{1}{203}$ of the mean value of W.

The values of A, omitting the last decimal figure as of no significance, are as follows :

| | | |
|-------------------------------|-------|-------|
| From experiments on Iron ring | ----- | ·0802 |
| “ “ tinned Iron ring | --- | ·0810 |
| “ “ Copper | --- | ·0813 |
| “ “ Brass | --- | ·0810 |
| “ “ German Silver | --- | ·0811 |

·0809 = mean

The maximum value exceeds the minimum by 1·37 per cent. The mean difference of the minimum and maximum from the mean is $\frac{1}{161}$ of the mean.

From these experiments on the rings, and from the value of A deduced from them, it appears that $W = 2T + P$ represents the equation of the forces acting on a floating ring.

On the value of the constant of the surface-tension of water.

The mean of twenty-eight determinations of the surface tension of water in grams per centimeter, made by physicists during the past sixty years, is ·0772. Nineteen of these determinations were deduced from measures on the ascent of water in capillary tubes and give a mean value of ·0769. These vary from ·0747 by Quincke to ·0812 as determined by Simon. The latter is 8·7 per cent greater than the former. The remaining nine determinations of the twenty-eight were made by measurements on drops and bubbles, adhesion of disks, pendent drops, weight of elevated meniscus adhering to a rectangular plate, extent and time of oscillations of falling drops, wave length of ripples, and by direct measure of tension of a film of water acting on a suspended rectangular frame. These vary from Lenard's ·0740, obtained from observations on the extent and time of oscillations of falling drops, to Quincke's ·0827, deduced from measurements on bubbles and drops. Quincke's value is 11·7 per cent higher than Lenard's.

The surface tensions given are reduced to their value at 0° by Brunner's formula, and are taken from a paper by T. Proctor Hall, *New methods of measuring the surface tension of liquids*, Phil. Mag., Nov. 1893, in which paper a complete list of the determinations of the surface tension of water is given in dynes. I have reduced them to grams per centimeter by dividing by 980·9.

The value ·0809 given by my experiments on the floating rings is $3\frac{1}{2}$ per cent higher than ·0772, the mean of all the determinations on the surface tension of water. However, Quincke* gives ·0827; Timberg,† ·0820; Weinberg,‡ ·0816, and Simon,§ ·0812.

* Pogg. Ann., cxxxix, p. 253.

† Beibl., xvi, p. 496, 1892.

‡ Wied. Ann., xxx, p. 545, 1887.

§ Ann. Chim. Phys., xxxii, p. 5, 1851.

On the determination of the surface tension of a solution of sodium chloride of a density of 1.2.

A wire of platinum $\frac{1}{16}$ mm thick made into a ring 5.04 cm in diameter, and provided with a wire yoke supporting a brass cup, floats readily on water. If we ascertain the weight per centimeter required to force the ring through the surface of the water, and subtract from this weight the upward hydrostatic pressure on a centimeter of the ring we will have a quantity which, compared with a similarly determined quantity, when the ring is placed on the solution of sodium chloride, will give the relative surface tensions of water and of the solution. The following experiments were made with the ring on water:

| | |
|--|-----------------------|
| Diameter of axis of ring..... | 5.04 ^{cm} . |
| Circumference of axis of ring.... | 15.83 ^{cm} . |
| Temperature of water and of salt solution | 16°. |

W.

2.248

.297

.291

.233

.285

.287

2.273 = mean.

$$\frac{W}{\text{circ}} = .14358 = w; \quad w - p = .14233$$

The following were the results of the experiments made with the platinum ring on the solution of sodium chloride.

$$\frac{W}{\text{circ}} = \frac{2.538}{15.83} = .1603 = w$$

$$w - p = .1603 - .0016 = .1587$$

Taking .0772 as the surface tension of water, we have for the surface tension of the solution of sodium chloride $\frac{.1587}{.1423} \times .0772 = .0860$. Frankenheim* gives .0840 at 19°, which reduced by Brunner's formula to 16° becomes .0844.

A peculiar phenomenon was observed during the experiments to find the weight necessary to sink the ring in the sodium chloride solution. There was observed a gradual

* Cohäsionslehre, Breslau, 1835.

diminution of this weight in each successive experiment. After each experiment with the ring on the salt solution it was placed in distilled water, vigorously agitated therein for a minute or two, then placed in fresh distilled water for several minutes, wiped dry and allowed to remain for about fifteen minutes before another experiment was made. The following table gives the result of six experiments.

| W |
|-------|
| 2.543 |
| 2.430 |
| 2.425 |
| 2.424 |
| 2.411 |
| 2.407 |

It was found that, if the ring after having been thoroughly freed of the salt solution was allowed to rest for a day, it recovered its primitive breaking weight. Thus an interval of a day existed between the following experiments.

| W |
|-------|
| 2.543 |
| 2.541 |
| 2.530 |

2.538 = mean.

A similar diminution of W in each successive experiment, but of greater extent, was observed in six successive experiments on the salt solution with a tinned iron ring.

The only explanation of the phenomenon that has occurred to me is that the salt solution in each successive experiment takes off a portion of the air condensed on the surface of the ring and gradually brings it towards that condition of the ring when it is freed of air, as by heat, and does not float at all. But why it takes twenty-four hours to recover its primitive surface, whereas, after having been heated to redness it recovers it in a half-hour, I cannot explain.

Uses of the platinum ring in measures of the degree of contamination of the surface of water, and in experiments on contaminated water contained in the trough of Miss Pockels.

If the platinum ring be loaded to, say, one-tenth of the weight required to make it sink and then floated on freshly distilled water, it will sink when, from any cause, the surface tension of the water has been lessened ten per cent. The duration of flotation of the ring is variable. On one day it floated during only two hours; on another day it floated for 9 hours;

on another day 5 hours. The same ring loaded so that it lacked 30 per cent of the breaking weight floated during 66 hours. The contamination of the water seemed more rapid during dry, windy and dusty weather than during, or just after a rain. The contamination, however, also proceeds from the vessel, either of glass or of metal, holding the water, as shown by Miss Agnes Pockels of Brunswick, Germany.* I have not given any study to the causes of the contamination of a surface of water exposed in the open air, because the results with the ring, though curious, are of little value unless connected with other observations on the conditions of the atmosphere. It may be that a floating platinum ring may be of use in determining the relative amounts of dirt or dust in the air on different days; but to be used for this purpose one must first accurately find out how much of the contamination is due to the substance of the vessel by experiments made on water in the trough of Miss Pockels inclosed in an air-tight vessel.

Several pleasing experiments may be made with the platinum ring floated on water in the trough devised by Miss Pockels. This ingenious and simple invention consists of a trough of tinned iron 70^{cm} long, 5^{cm} wide, and 2^{cm} deep, filled to its brim with water. A strip of metal longer than the width of the trough is placed athwart the latter with the plane of the strip in a vertical position. The lower edge of the strip touches the surface of the water. By sliding the strip from the extreme end of the trough the contaminated surface of the water is made smaller and more contaminated on the side of the strip towards which this is moving, while the surface of the water on the other side of the strip has been swept clean and may be regarded as a clean surface. The platinum ring is floated on this clean surface and the weight required to sink the ring is determined. Now load the ring till its weight is less than the weight required to sink it by 10, 20, 30, etc., per cent. If the ring is now floated near one end of the trough while the strip of metal is slid along from the other end of the trough towards the ring, the surface of the water on the side of the strip toward the ring becomes more and more contaminated till its surface tension can no longer hold up the ring, and this sinks. Knowing the percentage of the breaking weight with which the ring is loaded and the fraction of the length of the trough to which the strip has been moved when the ring sank, we have the degree of contamination of the water of the trough before it was altered by the sliding strip.

There is no difficulty in obtaining a contamination surface. The surface of distilled water is contaminated soon after it has

*Surface Tension. A letter to Lord Rayleigh from Miss Pockels. *Nature*, March 12, 1891.

been poured into the trough; and no doubt was contaminated before it was poured from the bottle. If, however, a greater degree of contamination of surface is required it may be obtained by introducing into the water the point of a needle which has been coated with a thin film of oil, or, by scraping camphor over the surface of the water. A very thin film of oil, whose thickness Lord Rayleigh has fixed as equal to $1\frac{1}{2}$ millionth of a millimeter, or $\frac{1}{4000}$ of the length of a wave of yellow light, is sufficient to stop the motions of minute, thin scrapings of camphor.* If the motions of the camphor, however, continue with the degree of contamination we have given the water, we can stop these motions by increasing the contamination on sliding the metal strip along the trough and contracting the contaminated surface. If the ring floating on this portion of the liquid is now loaded till it sinks, we have the means of knowing the diminution of the surface tension required to stop the motions of the camphor.†

If the ring is placed near one end of the trough and the strip of metal is slid from the extreme end of the trough towards the ring, but not near enough to it to cause such lowering of surface tension that the ring sinks, one will observe the ring to move slightly away from the moving strip. This is owing to the contamination of the surface being slightly greater, and the surface tension lower, near the side of the strip towards the ring than it is at a distance from the strip, near to and beyond the floating ring. The consequence is that the surface film surrounding the ring and beyond it contracts and carries the ring away from the strip. The strip now remaining stationary, we have a lower tension on the contaminated or ring side of the strip than on the other side, where the surface of the water is clean; therefore on sliding the strip backwards with a gradually increasing velocity over this clean surface, or, on removing the strip from the trough, the clean surface contracts and keeps on contracting till it has so stretched the contaminated surface that it covers uniformly the whole surface of the trough. The ring, hung in this surface which is being stretched, moves with it and is seen to go rapidly towards the other end of the trough.

Metals and glass float on water when the film of air condensed on their surfaces has been driven off by heat.

If platinum, gold, or silver wire of $\frac{4}{10}$ mm in diameter is formed into a ring, heated to redness and when cold placed on

* On Foam. A lecture by Lord Rayleigh before the Royal Institution. March 28, 1890.

† I have been prevented from making this interesting experiment by a painful and long illness from which I have not yet recovered.

water, it sinks. If the ring is wiped dry, and then placed on the water, it sinks; but if wiped dry and exposed to the air for from 10 to 15 minutes it will float. Also, a ring of one of these metals which has been heated to redness and which has not been wetted will float after having been exposed to the air for about a half hour.

Wires of platinum, gold, and of silver of $\frac{1}{10}$ mm in diameter, and wires of aluminum, copper, brass and german silver of 1 mm in diameter floated when gently placed on the surface of water by means of a fork made of fine wire. These wires were 5 cms. long. All of these wires sank after having been passed slowly to and fro six times in the lower part of a spirit flame, and recovered their property of flotation after they had remained from two to five minutes in the air.

Glass rods of $\frac{1}{2}$ mm in diameter and 5 cm long behaved in similar manner to the wires. If a rod of glass recently drawn out in a spirit flame and just cold is placed on water it sinks. After a freshly made glass rod has remained exposed to the air for about 15 minutes it will float. If a recently made glass rod which has just sunk in water be withdrawn, wiped dry, and exposed to the air for from 10 to 15 minutes, it will float. These floating glass rods, however, do not, as in the case of the wires, give straight lines of demarkation, between the surfaces of the glass and the water. At some places the water wets and covers the glass, at others it does not wet the glass, and the lines of demarkation of the glass and water are jagged. This rod, placed vertically in the water, shows an ascending meniscus at the parts where it was wetted when floating and a depressed meniscus at the parts where it repelled the water. If a glass rod is sunk and then brought to the surface of the water and floated and this operation repeated several times, the rod becomes more and more repellent of water, and when depressed in the water-surface by a fine wire the lines of separation of the glass and water becomes almost straight and the rod acts like one of clean metal. The rod can now be depressed, by a fork of fine wire, to nearly 3 mm below the general level of the water. These experiments show how soon the surface of glass is contaminated by exposure to water and air, this contamination reversing indeed the attractive property of *clean* glass for water.

The experiments on the metals show that when their surfaces are freed of air they sink, and that after the film of air has recondensed on their surfaces they float. In other words, in the first case the metals are wetted and in the second they are not. Considering fig. 5, it is evident that the dry surface of the wire between the two opposite depressed surfaces of water could not exist if the water wetted the wire as it would wet a ring made of clean glass. At the same time, though the water does not wet the wire as water wets glass, yet the water

is attracted by the wire so that it adheres to it with such force that it can take the curvature required to withstand the inward hydrostatic pressure on the two depressed water surfaces. Another observation is of interest here. On observing the wire between the depressed sheets of water through a microscope, as in fig. 6, one does not see the opposite surfaces of the water gradually and smoothly slide over the wire and approach one another as the wire goes deeper and deeper in the depression, but the terminal edges of the depressed water surfaces leave the wire to approach one another in a series of jumps. These releases of the two edges of the water surfaces from the wire do not take place uniformly and simultaneously along the whole of these edges, but take place at many points irregularly distributed along the lines of demarkation of the wire and water.

The attraction existing between the wire and the water is shown by lifting a floating ring above the general surface of the water when the water adheres to the ring and may be lifted several millimeters. If the ring be lifted quickly we often obtain a catenoid of elevated water-film apparently a centimeter or more in height. When the elevated film breaks it generally forms into drops regularly spaced around the ring.

The film of air on the surfaces of the rings must be very thin, probably a small fraction of the radius of molecular activity which, according to Plateau and Quincke, is about 0.00005^{mm} , or $\frac{1}{20}$ of a micron, or about $\frac{1}{12}$ of the wave length of sodium light. If, however, the air be condensed on the metals to the same degree that oxygen is occluded by platinum black, the air film may have the density of water and its attraction may be of an order approaching that of the metal itself for water. This condition, which probably exists, renders futile the determination of the thickness of the air film by optical methods. Professor Wright, of Yale University, suggested to me to determine if total reflection took place from a water surface which was in contact with a surface of metal. I made the experiment in the following manner. A cubical vessel made of plates of glass, such as is used in Plateau's experiments on figures of oil in dilute alcohol, was about two-thirds filled with water, and a black cross on a white ground was seen by total reflection from the surface of the water. A floating disk of aluminum was moved till it came over the portion of the water from which the reflection had taken place. The reflection was destroyed by the presence of the disk and this destruction took place either with a disk whose surface was partly polished or with a disk whose under surface had been made of a non-reflecting grey by the action of caustic soda. This fact is interesting, but I do not see how it can give information even as to the limiting thickness of the film of air of whose condensation and index of refraction we know positively nothing.

ART. XXV. — *Note on Computing Diffusion*; by GEO. F. BECKER.

DIFFUSIVE phenomena have become of great importance to geologists. As every one knows, Lord Kelvin's famous inquiry into the age of the earth is based on the diffusion of heat in a cooling globe of large radius. The modern theory of the differentiation of rock magmas also is founded on phenomena of molecular flow, the least complex of which is the simplest case of liquid diffusion. The diffusion of motion in a viscous fluid is subject to the same laws and is capable of geological applications. Possibly even the diffusion of current density in a homogeneous conductor may eventually be made to contribute to a knowledge of the earth's interior.

The computation of the simplest diffusive phenomena has a formidable appearance to most geologists, while to those who are mathematically inclined the reckoning appears inelegant and clumsy. It is probable that every one who has actually computed diffusions has seen how the subject could be simplified, but each appears to have shrunk from the trouble of setting the matter straight. I shall attempt to make the subject so easy that no geologist will hesitate to compute any case which may help him to frame a theory or to test an hypothesis.

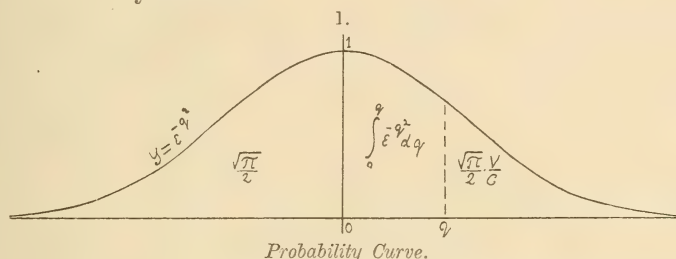
In "linear" motion as defined by Fourier the subject of motion, or the "quality" as Lord Kelvin calls it, varies only in one direction; in other words, it remains uniform at all points in any one plane at right angles to this direction. Qualities in this sense are for example the temperature of a body, the amount of substance in solution per unit volume, the velocity of a viscous fluid. For qualities obeying the law of diffusion the differential equation is

$$\frac{dv}{dt} = \kappa \frac{d^2v}{dx^2}.$$

Here v is the quality, t the time, x the distance from the plane of contact between the subject of diffusion and the medium into which it diffuses, and κ is the "diffusivity" assumed to be constant. The equation may be expressed by the statement that the time rate of change of quality is proportional to the space rate of the space rate of change of quality. It is usual with English writers to apply the C. G. S. system to these measurements. That system attains a most convenient uniformity, though only at the expense of some very awkward numbers.

The simplest case of linear diffusion arises when the diffusing quality at the initial plane is kept constant and when the

space into which it diffuses may be regarded as infinite. The quality at any distance measured perpendicularly to the initial plane is then proportional to the area of the "probability curve" taken between certain limits. Now this area between any limits has repeatedly been computed and tabulated, because it is of importance in the astronomical discussion of refraction, in the theory of probabilities, etc. Thus it is only needful to apply these tables to find the distribution of quality at any time or for any distance.



For this simplest case of diffusion let c be the initial concentration and let also

$$q = \frac{x}{2\sqrt{\kappa t}};$$

then the quality v in terms of the initial concentration is simply*

$$\frac{v}{c} = \frac{2}{\sqrt{\pi}} \int_0^{\infty} e^{-q^2} dq.$$

Here q appears as the abscissa of the probability curve. The value of the integral in this expression has been tabulated, but more usually it is the area from zero to q instead of that from q to infinity which is computed. That is a mere matter of detail; for the whole area from zero to infinity is simply $\sqrt{\pi}/2$, so that a knowledge of either part of the area leads immediately to the determination of the other. If the accessible tables have the usual form, it is only necessary to write the equation as follows:—

$$\frac{v}{c} = 1 - \frac{2}{\sqrt{\pi}} \int_0^q e^{-q^2} dq.$$

There is thus no mystery or difficulty about computing diffusion when κ is known. Of the three quantities x , t , and v ,

* The truth of this theorem is easily tested; but its proof does not come within the scope of this note.

any two may be assumed and the corresponding value of the third found. The practical awkwardness of the results is a consequence of the fact that the tabulations are made with q for an argument. Hence, the least laborious method is to assume q at some tabulated even value, find x or t from the

2.

*Diffusion Curve.*

first of the above equations and v from the second. Thus assuming $t = 86400$ seconds (one day) and $\kappa = \cdot 00001$, which is about the value for common salt, and taking $q = \cdot 4$, one finds $x = 0\cdot 7436$ and by the help of the tables of the integral, $v = 0\cdot 5716 c$. A series of corresponding values thus obtained for v and x is not easily grasped numerically. On the other hand, these values are readily plotted. It is apparently for this reason that Lord Kelvin has on various occasions represented diffusion by diagrams. Messrs. King and Barus used the same device, and the system of curves by the aid of which Lord Kelvin proposed the computation of diffusions* is mainly useful for the same reason.

The abscissa of the probability curve is not the natural independent variable for calculating diffusions. Greatly preferable is the quality, v/c . It is entirely possible to employ it in this way even with the tables hitherto published. The tables of the integral can be entered with rounded values of v , and corresponding values of q , containing as many significant places as desirable, can then be interpolated. From such values of q one can obtain x and the result is a table showing the distances for rational values of the quality. This, however, is a tedious process, since, for a satisfactory degree of accuracy, the interpolation must be made by second differences.

What is needed to facilitate computation of diffusions in a neat form, such as will not require diagrams to render the relations clear, is a table in which q , or better $2q$, is expressed

* Rep. Brit. Assoc., 1888, p. 571.

in terms of v/c . Such a table is given below, but only in skeleton for intervals of v/c of .05. It will, I think, suffice for the needs of geologists, and it is hardly worth while to extend it to single hundredths unless some desire for such an extension should be manifested.* Knowing $2q$ for a stated value of v/c the value of x in centimeters follows easily from the equation,

$$x = 2q\sqrt{\kappa t}.$$

To find the distance at which any chosen quality exists in linear diffusion after the lapse of t seconds, it is now only necessary to add half the logarithm of κt to $\log 2q$ and take the number corresponding to the sum from a table of common logarithms. This is a labor from which no geologist interested in diffusion can shrink.

The values of $2q$ are given in part because they are the distances in centimeters after the lapse of one particular time, that, namely, which is the reciprocal of the diffusivity. Thus in the case of salt with a diffusivity of .00001, after a lapse of 100,000 seconds, or some 28 hours, $\kappa t = 1$ and $2q$ represents the distances answering to v/c .

If one is not anxious to preserve the severe simplicity of the C. G. S. system, the day or the year is a more convenient time unit than the second for computing diffusions of liquids as well as of heat in large masses of matter such as the earth. I have therefore tabulated δ as defined by the expression

$$x = 2q\sqrt{86400 \cdot \sqrt{\kappa\Delta}} = \delta\sqrt{\kappa\Delta},$$

where Δ is the time expressed in days; and also γ in

$$x = \delta\sqrt{365 \cdot 2422 \sqrt{\kappa\Gamma}} = \gamma\sqrt{\kappa\Gamma}$$

where Γ is the time expressed in years. To make the logarithms of $2q$ useful in this connection it may be noted that

$$\log \delta = \log 2q + 2.46826; \log \gamma = \log 2q + 3.74955.$$

In German papers it is usual to state the diffusivities of liquids in terms of days, so that if λ is the diffusivity thus stated $\lambda = 86400 \kappa$ and

$$x = 2q\sqrt{\lambda\Delta},$$

Of course the tabulated values of δ answer to a period for

* The values of q were computed from the seven-place table of the integral given by Lord Kelvin, *Phys and Math. Papers*, vol. iii, 1890, p. 434. The interpolations were made by a known formula of the same order of accuracy as the formula for second differences, and the results were tested by substitution in the formula for second differences. Seven-place logarithms were used. The abbreviation to five places introduces an apparent inaccuracy, inasmuch as the $\log 2q$, as tabulated, sometimes varies in the last place from the five-place \log of the tabulated value of $2q$. The tabulated logarithms are, however, the nearest in five places to the values of $2q$ expressed in seven places.

which $\Delta = 1/\kappa$, or in the case of salt a period of 100,000 days, while the values for γ correspond for salt to a lapse of time of 100,000 years.

In connection with this table it may be convenient to set down a few diffusivities interesting to the geologist, either immediately, or for comparison with the diffusivity of rock magmas. The data for the diffusion of heat and motion are taken from Lord Kelvin's memoir on Heat. The diffusivities of solutions were all originally published in terms of days, not seconds. In the list below they are stated both in this way under λ and in seconds under κ . In choosing illustrations from the many experiments of Scheffer and of Schuhmeister* I have when practicable selected two nearly at the same temperature with different concentrations, and a third at a different temperature but with concentration as nearly as may be equal to that of one or other of the first two. There seems no doubt that κ in the case of liquids varies both with concentration and temperature. The variations of κ however, are far from complete elucidation.

Mr. Schuhmeister remarks that "the rapidity of diffusion runs almost exactly parallel with the larger or smaller values of the coefficient of friction," but makes no further comment on the relations of viscosity to diffusivity. In an investigation undertaken by Mr. A. Sprung† in Prof. Wiedemann's laboratory, for the purpose of determining the viscosity of salt solutions over wide ranges of temperature and concentration, diagrams and tables are given which enable one to fix the viscosities of seven salts of which Mr. Schuhmeister has determined the diffusivities for the same temperature and for nearly the same concentration. Sprung's concentrations are given in terms of the weight of anhydrous salt per 100 parts by weight of solution. Schuhmeister's data are for weight of anhydrous salt per unit volume of solution. The concentrations being 1/10 and the temperature 10° C., κ the diffusivity, and μ the coefficient of viscosity, the results of the two observers are expressed in the first three lines of the following little table.

| Salt | KBr | KI | KCl | NaCl | CaCl ² | Na ² SO ⁴ | MgSO ⁴ |
|---------------------------|-------|-------|-------|-------|-------------------|---------------------------------|-------------------|
| $\kappa \times 10^6$ | 13.08 | 12.96 | 12.73 | 9.72 | 7.87 | 7.64 | 3.24 |
| μ | 0.126 | 0.124 | 0.128 | 0.156 | 0.169 | 0.179 | 0.247 |
| $\kappa\mu^2 \times 10^6$ | 0.207 | 0.199 | 0.208 | 0.236 | 0.224 | 0.244 | 0.198 |

* Mr. J. Schuhmeister's investigation, undertaken at Prof. J. Stefan's advice, appeared in *Wieu. Sitz. Ber. Ak. Wiss.*, vol. lxxix, 1879, Part II, p. 603. At the close of the paper mean values of λ are given for 10° C. Stefan recomputed Graham's diffusion experiments. His paper is in the same volume as Schuhmeister's, p. 161. Mr. J. D. R. Scheffer's memoir on diffusion is published in *Verh. Kon. Ak. van Wet.*, xxvi, Part, 1888, with separate pagination.

† *Pogg. Ann.*, vol. clxx, 1876, page 1.

In the last line I have shown the product $\kappa\mu^2$, which evidently varies slowly and irregularly. Expressed in two figures the average of the two sulphates gives 0.22; the average of the three chlorides gives 0.22; the average of the five alkaline salts gives 0.22; the average for the seven compounds is 0.22. The average for the three potassium salts on the other hand is only 0.20, and the average for the two sodium salts is 0.24.

The variation of $\kappa\mu^2$ from a single value is perhaps not greater than might be expected from the data on diffusivity (which, as Mr. Schuhmeister himself points out, accord only approximately) if $\kappa\mu^2$ were really a constant. It is clear that the hypothesis—diffusivity is inversely proportional to the square of the viscosity for uniform temperature and concentration, expresses approximately the facts for these seven compounds. The number of compounds is small, but it embraces salts of four bases and of four acids showing rather a wide range of diffusivities and of viscosities. The probability that the accord is a mere coincidence seems to me extremely slight, and I infer that the hypothesis just stated probably expresses, at least roughly, the relations of diffusivity to viscosity for an important class of compounds. Should it prove that solutions such as rock magmas are to be included in this class, it would greatly facilitate the discussion of rock differentiation. Some approach to a quantitative determination of the viscosity of lavas might be attained. Direct investigation of their diffusivity would seem impossible.

Liquids diffusing into water.

| Solution of | Temp. | Concentration. | λ | κ | Authority. |
|---------------------|-----------|--|-----------|-------------|--------------------|
| Chlorhydric acid, | 11.° | 1HCl/7.17H ² O | 2.671 | .000 030 91 | Scheffer. |
| " | 11.° | 1HCl/108.4H ² O | 1.837 | .000 021 26 | |
| " | 0.° | 1HCl/6.86H ² O | 2.080 | .000 024 07 | |
| Sulphuric acid, | 7.5° | 1H ² SO ⁴ /685.7H ² O | 1.042 | .000 012 06 | |
| " | 8.° | 1H ² SO ⁴ /36.2H ² O | 1.008 | .000 011 67 | |
| " | 13.° | 1H ² SO ⁴ /35.4H ² O | 1.244 | .000 014 40 | Schuhmeister. |
| Sodium chloride, | 7.7° | .147 85 g. per cm ³ | .810 | .000 009 38 | |
| " | 8.3° | .322 38 " | .798 | .000 009 24 | |
| " | 14.° | .139 75 " | .9015 | .000 010 43 | |
| " (Mean), | 10.° | .10 | .840 | .000 009 72 | |
| Sodium carbonate, | 5.5° | .099 86 " | .319 | .000 003 69 | |
| " | 9.5° | .134 03 " | .375 | .000 004 34 | |
| " | 20.5° | .182 42 " | .613 | .000 007 10 | |
| " (Mean), | 10.° | .13 | .390 | .000 004 51 | |
| Sodium sulphate, | 5.3° | .046 19 " | .614 | .000 007 11 | |
| " | 10.7° | .073 24 " | .678 | .000 007 85 | |
| " (Mean), | 10.° | .10 | .660 | .000 007 63 | |
| Copper sulphate, | 8.1° | .177 64 " | .212 | .000 002 45 | |
| " | 8.1° | .088 57 " | .230 | .000 002 66 | |
| " | 4.6° | .129 26 " | .203 | .000 002 35 | |
| " (Mean), | 10.° | .10 | .210 | .000 002 43 | |
| Magnesium sulphate, | 4.5° | .244 05 " | .209 | .000 002 42 | Graham; Stefan. |
| " | 9.4° | .309 92 " | .279 | .000 003 23 | |
| " | 12.7° | .311 56 " | .305 | .000 003 53 | |
| " (Mean), | 10.° | .10 | .280 | .000 003 24 | |
| Cane sugar, | 10.° | 10 per cent | .456 | .000 005 28 | |
| Caramel, | 10.°-11.° | 10 per cent | .047 | .000 000 54 | |

Diffusion of heat and motion in C. G. S. units.

| Subject of Diffusion. | Medium. | κ | Authority. |
|-----------------------|------------------|----------|------------------------|
| Heat, | Iron, | ·225 | Angstrom and Tait. |
| " | Sandstone, | ·023 11 | Forbes and W. Thomson. |
| " | Trachyte, | ·010 28 | Ayrton and Perry. |
| " | Trap, | ·007 86 | Forbes and W. Thomson. |
| " | Average of rock, | ·01 | " " |
| Laminar motion, | Air, | ·053 | Stokes and Maxwell. |
| " | Water at 10° C., | ·013 2 | Poiseuille, Stokes. |

Diffusion Table, giving distances in terms of quality, v/c , after the lapse of $1/\kappa$ seconds, days or years.

| v/c | $\log. 2q.$ | $2q$ in cm. | δ in cm. | γ in cm. |
|-------|-------------|-------------|-----------------|-----------------|
| 0·0 | $+\infty$ | ∞ | ∞ | ∞ |
| ·005 | 0·59876 | 3·9697 | 1166·9 | 22300· |
| ·01 | 0·56143 | 3·6428 | 1070·8 | 20464· |
| ·05 | 0·44276 | 2·7718 | 814·74 | 15571· |
| ·10 | 0·36664 | 2·3262 | 683·75 | 13067· |
| ·15 | 0·30874 | 2·0358 | 598·40 | 11436· |
| ·20 | 0·25825 | 1·8124 | 532·73 | 10181· |
| ·25 | 0·21134 | 1·6268 | 478·19 | 9138·9 |
| ·30 | 0·16606 | 1·4657 | 430·84 | 8233·9 |
| ·35 | 0·12114 | 1·3217 | 388·50 | 7424·8 |
| ·40 | 0·07563 | 1·1902 | 349·85 | 6686·2 |
| ·45 | 0·02870 | 1·0683 | 314·02 | 6001·3 |
| ·50 | 9·97949—10 | ·95387 | 280·38 | 5358·4 |
| ·55 | 9·92704 | ·84536 | 248·48 | 4748·9 |
| ·60 | 9·87018 | ·74161 | 217·99 | 4166·1 |
| ·65 | 9·80734 | ·64172 | 188·63 | 3604·9 |
| ·70 | 9·73634 | ·54493 | 160·17 | 3061·2 |
| ·75 | 9·65381 | ·45062 | 132·46 | 2531·4 |
| ·80 | 9·55431 | ·35835 | 105·33 | 2013·1 |
| ·85 | 9·42725 | ·26745 | 78·615 | 1502·4 |
| ·90 | 9·24972 | ·17771 | 52·236 | 998·31 |
| ·95 | 8·94783—10 | ·08868 | 26·067 | 498·17 |
| 1· | $-\infty$ | 0· | 0· | 0· |

Washington, D. C., February, 1897.

ART. XXVI.—*A relatively Acid Dike in the Connecticut Triassic area*; by EDMUND OTIS HOVEY.

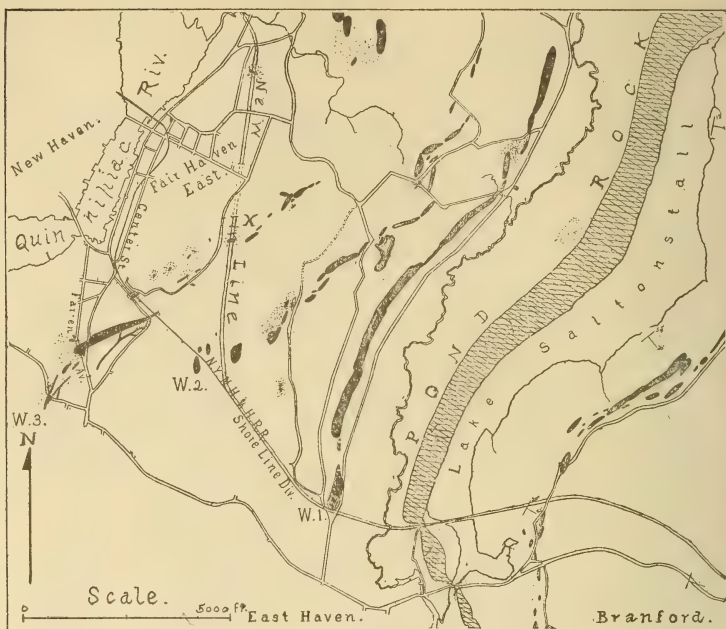
DURING the years 1893 and 1894 the New York, New Haven and Hartford Railroad Company made great changes in the layout of its Shore-line division, especially in the eastern part of the town of New Haven, Conn. Here it abandoned its old route entirely and cut its way through the Triassic sandstone by means of a deep trench and a long tunnel nearly half a mile east of its old course. For a considerable portion of the distance the new cut (50 feet deep in places) followed a shallow valley at the base of one of the low bluffs of sandstone which characterize the topography of the region. This proved to be one of the numerous fault planes of the district and the sandstone encountered was much broken and slickensided, so much so as to necessitate the lining of the entire tunnel with heavy brickwork. The cut revealed the presence of several dikes which are of some interest. All of them are transverse to the strike of the sandstone and the three largest (which are of ordinary diabase) and southernmost connect two of the ranges of dikes indicated on Percival's map* and shown in more detail on that published by the present writer,† a portion of which is reproduced here, with additions, as figure 1. The two smallest dikes as shown in the east wall of the cut coalesce in the floor, appearing as one in the west wall of the cut. The rock of these is different from the diabase of the region in chemical composition and structure, and approaches keratophyre, to which class it is provisionally referred. Slickensided surfaces in the middle of the largest dike (50 feet wide) show that some differential movements in the region have acted on the trap as well as the sandstone.

The relations of the dikes to one another and to the sandstone are so clearly indicated by the accompanying plan (fig. 3) and section (fig. 2) that extended comment on this feature is unnecessary. The dikes are seven in number, but Nos. 1 and 1*a* are evidently parts of the same; Nos. 2 and 3 probably meet a little east of the cut and Nos. 4 and 4*a* meet in the floor of the cut, so that the number of relatively independent dikes is four or, at most, five (see fig. 3). They vary in size from one or two inches up to about fifty feet, and extend in a belt about 440 feet wide diagonally across the railroad cut from northeast to southwest, the smallest ones being at the north and about

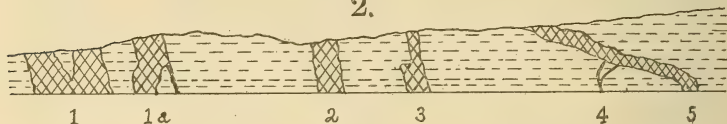
* Geol. Rept. of Conn., 1842, J. G. Percival. Reproduced in part in Dana's Manual of Geology. Fourth edition. p. 801, 1895.

† This Journal, III, xxxviii, pl. IX, Nov., 1889.

1.



2.



3.

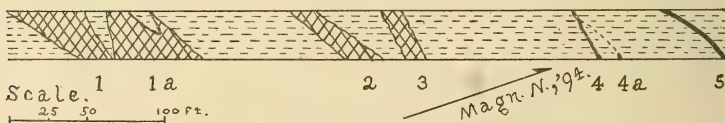


FIG. 1. Map of part of the towns of New Haven, East Haven and Branford, Conn. Solid black and cross-lined areas indicate exposures of trap; dots indicate sandstone associated with the trap. The dikes discussed in the present paper are located at X.

FIG. 2. Section of sandstone and trap as exposed in the west wall of the railroad cut at X, on the map. Scale as in figure 3.

FIG. 3. Plan of floor of railroad cut at X, on the map. In this and the preceding figure sandstone is indicated by the broken lines and trap by the solid black and crossed lines. Horizontal and vertical scale the same.

110 feet from the southern entrance to the tunnel, which passes under East Grand avenue half a mile east of the Quinnipiac river. This is the best place near New Haven for the study of the phenomena of dikes: the differences in coarseness of grain in the dikes themselves on account of different widths; the increase in coarseness from each wall toward the center, especially in the larger dikes; columnar structure perpendicular to the walls in the heavy dikes; inclusion of country rock in the mass of a dike and the effect upon the igneous rock and the included block; contact phenomena on sandstone strata of varying nature, etc. Two-fifths of a mile north of the tunnel and a fourth of a mile from the Fair Haven station of the railway, an isolated dike crosses the cut. It is very irregular, from two to four feet wide, and trends N. 60° W. (magnetic) and hades 25° to 30° to the northeast. The course of the cut and tunnel is N. 18° E. (Observation made in October, 1894.)

The dikes which furnish the rock which is such a departure from the normal diabase of the region as to merit special description are numbered 4 and 4a on the plan, but 4a appears only in the east wall of the cut and although it is four or five inches wide at the level of the track, it pinches out about fifteen feet above, and does not reach the surface. In appearance it is like number 4 and is an offshoot from it. No. 4, from which the hand specimen about to be described was taken, is less than two inches (45^{mm}) wide at the level of the railway track on the east side of the cut and slowly and irregularly increases to about 8 inches in width toward the surface. The course across the bottom of the cut is about N. 80° W. (magnetic) and its hade on the east side of the cut is 33° to the south, but its inclination changes to the other side of the vertical on the west side of the cut and it passes very irregularly through the sandstone, separating into two branches as shown in the figure and being apparently intersected by No. 5. The color of No. 4 near the bottom of the cut on the east side is a light brick-red, very much like that of the inclosing sandstone but banded with different shades parallel to the sides of the dike and having small bluish green spots (chlorite) along the middle; green predominates above. On the west side the dike is grayish green with red edges. No. 4a is red. No. 5 is much wider than either of these, $3\frac{1}{2}$ feet (1.1 meter), and its color and appearance are like those of the well known diabase dikes of the region: a very dense, greenish black rock with phenocrysts of augite. Under the microscope the rock of No. 5 presents a variation from the ophitic structure of typical diabase in that the augite of the groundmass is granular crystalline around the labradorite instead of being in broad plates penetrated by the feldspar. It is evident that dikes No. 4 and

4a cannot be offshoots from No. 5, on account of the difference in microscopical structure and mineralogical composition.

Petrography.—The hand specimen from dike No. 4 represents the whole breadth of the dike at the place from which it was taken and is from 4 to 4.5^{cm} wide. The texture is aphanitic at the sides and somewhat coarser in the middle, some of the larger feldspar phenocrysts and many areas of calcite and chlorite being discernible with an ordinary hand lens. Under the microscope the gradual increase in coarseness from wall to center is well shown. The rock consists essentially of feldspar. There are two sets of phenocrysts of feldspar. One is made up of relatively large tabular, cuboidal and lath-shaped twinned crystals which tend to form groups of twos and threes. The angles of extinction measured on the twinning trace, 18° to 19° on each side, and the predominance of soda shown by the chemical analysis indicate the probability of these being albite. The other and by far the larger set of feldspar phenocrysts consists of minute acicular crystals, which are scattered very thickly through the section where it cuts the middle of the dike, but become less numerous toward the sides. These minute crystals seem to be simple (not twinned) and are referred to anorthoclase, on account of the chemical analysis. They show a tendency toward prolongation of the corners, producing forms not unlike those of orthoclase described by J. P. Iddings* from the rhyolite of Pinto Peak, in the Eureka district, Nevada, in which the extensions do not diverge.

The relations of the two sets of feldspar phenocrysts seem to indicate that the groups of relatively large crystals (albite) are older than the others. The albite areas also show a few inclusions and some alteration.

The ferro-magnesian minerals are conspicuous by their absence from the thin sections studied, but the areas of secondary calcite and chlorite for the most part have definite outlines which strongly suggest the original presence of phenocrysts of pyroxene (augite) in the rock. In some instances these areas are partly penetrated by the acicular crystals of feldspar, somewhat after the manner of diabase augite and feldspar.

The base or groundmass is cryptocrystalline and is made up for the most part of crystals like the smaller feldspar phenocrysts. Sphaerocrystalline structure was observed in some places. Some areas are not resolved by a No. 7 Fuess objective, but may be devitrified glass, as they affect polarized light.

Chemistry.—A chemical analysis of this peculiar dike was very kindly made for the writer by Dr. H. S. Washington with

* Hague, *Geology of the Eureka District*, U. S. G. S., Mon. xx, p. 378, pl. iii, fig. 14, 1892.

the results given in column A. Column B gives an analysis of New Haven (West Rock) diabase by G. W. Hawes,* introduced for the sake of comparison as illustrating the normal diabase. The analysis given in column A was made on mate-

| | A | B |
|--|--------|---|
| SiO ₂ | 60.13 | 51.78 |
| TiO ₂ | tr. | 1.41 |
| Al ₂ O ₃ | 20.47 | 12.79 |
| Fe ₂ O ₃ | 1.04 | 3.59 |
| FeO..... | 0.72 | 8.25 |
| MnO..... | tr. | 0.44 |
| MgO..... | 1.15 | 7.63 |
| CaO..... | 2.59 | 10.70 |
| Na ₂ O..... | 9.60 | 2.14 |
| K ₂ O..... | 1.06 | 0.39 |
| Ign. (CO ₂ and H ₂ O)..... | 3.44 | H ₂ O 0.63 P ₂ O ₅ 0.14 |
| | 100.20 | 99.89 |

rial dried at 110° C. The specific gravity of the rock at 11° C. was 2.63 (Washington). Since the powdered rock effervesces rather strongly on the addition of cold HCl and considerable calcite is seen under the microscope, the loss on ignition must be largely CO₂.

This composition indicates that the rock belongs to the group of keratophyres (or possibly the bostonites of Rosenbusch), though the percentage of Al₂O₃ is rather high and the soda predominates over the potash to a greater degree than usual. About 87 per cent of the rock is feldspar and it would all seem to be anorthoclase, with the exception of the albite phenocrysts. The rock shows more CaO and MgO than the keratophyres quoted by Zirkel in his "Lehrbuch der Petrographie," but the excess of the former may be accounted for by the amount of secondary calcite present in it.

One of the striking features of the Triassic igneous rocks of the Atlantic border from Nova Scotia to North Carolina is their uniformity in appearance and in mineralogical and chemical composition. Particular emphasis has been put upon this feature by J. D. Dana† and it has been referred to by many of the writers on these Triassic areas. In his treatise on "The Newark System," I. C. Russell‡ has noted this uniformity in

* This Journal, III, ix, 186, 1875, and U. S. Nat. Mus. Prcc., vol. iv, p. 132, [1881] 1882.

† This Journal, III, vi, 104-115. Also in his Manual of Geology and elsewhere.

‡ Bull. U. S. Geol. Survey, No. 85, pp. 67, 68, 1892.

these igneous rocks and has given a complete series of references to papers dealing with their mineralogical and their chemical composition, to which the reader is referred for any further details. H. D. Campbell and W. G. Brown,* however, describe petrographically and give the chemical analyses of two trap rocks from the Triassic of Culpeper county, Virginia, which depart from the "normal diabase" of Hawes and other observers. One of these is a hypersthene-diabase and the other an olivine-hypersthene-diabase. Another departure from the monotonous trap has been reported by L. S. Griswold,† who describes a very basic dike consisting essentially of augite, hornblende and biotite, with almost no feldspar, from Beseck Lake, near Baileyville, Conn., but gives no chemical analysis of the rock. The three instances of variation just cited are all of rocks as basic as or more basic than the normal or average diabase of the Triassic areas mentioned. The dike described in the present paper is the first one to be recorded from these areas in which the rock is acid or relatively acid.

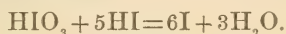
* Bull. Geol. Soc. Amer., ii, 339-347, 1891.

† Bull. Mus. Comp. Zool., xvi, 239-242, 1893.

ART. XXVII.—*The Application of Iodic Acid to the Analysis of Iodides*; by F. A. GOOCH and C. F. WALKER.

[Contributions from the Kent Chemical Laboratory of Yale University.—LXIII.]

It has long been understood that iodic acid is easily and completely reduced by an excess of hydriodic acid with the liberation of iodine according to the equation :



To apply this reaction to the quantitative estimation of iodic acid, it is only necessary to add to the free iodic acid or soluble iodate an excess of a soluble iodide, to acidify—best with dilute sulphuric acid—and to titrate the iodine thus set free with sodium thiosulphate, one-sixth of the iodine found being credited to the iodic acid.

It has been shown recently by Riegler* that this reaction may be also applied to the quantitative estimation of iodides, the iodine set free upon the addition of a known excess of iodic acid to the iodide solution being removed by petroleum ether, and the residual iodic acid titrated directly with sodium thiosulphate.

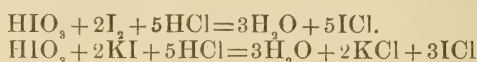
The present investigation was undertaken to define more particularly the limit of applicability of the reaction and to establish, if possible, a direct method for the quantitative estimation of iodides, dependent upon the action of iodic acid or an iodate in the presence of free sulphuric acid, neutralization of the solution by means of an acid carbonate, and titration of the free iodine by arsenious acid—five-sixths of the iodine thus found being credited to the iodide to be estimated. It has been found that by fulfilling certain necessary conditions, the proposed method is entirely successful, so far as concerns the estimation of iodine in iodide solutions free from large amounts of chlorides as bromides.

In a system containing a considerable quantity of free iodine with variable amounts of the other reagents mentioned, as well as possible impurities, it is conceivable that secondary reactions may occur, depending largely on conditions of mass, time and temperature, and of a sort likely to alter the amount of recoverable iodine, or to exert an excessive oxidizing influence on the arsenious acid finally titrated. It has been established by Schönbein, Lunge and Schoch, and others, that iodine forms compounds with the alkalis of the type R-O-I , and Phelps† has recently found that the formation of some such com-

* Zeitschr. für Anal. Chem., xxxv, 305.

† This Journal, ii, 70, 1896.

pound, accompanying the iodate naturally expected, is distinctly recognizable when iodine and barium hydroxide interact at ordinary temperatures. It has been shown, also, in a former paper from this laboratory* that free iodine or an iodide interacts very easily with iodic acid in the presence of dilute hydrochloric acid with the formation of iodine monochloride, according to the equations:



Moreover, organic compounds containing the groups $-\text{I}=\text{O}$ and $-\text{I}=\overset{\text{O}}{\underset{\text{O}}{\text{O}}}$, in which iodine seems to be analogous to nitrogen, result in great variety from the oxidation of halogen substitution products. It would seem, therefore, that the formation of inorganic reduction products of iodic acid under the conditions likely to obtain in this analytical process might be by no means beyond the bounds of possibility.

A few simple qualitative tests to determine the possibility of interaction between small quantities of iodine and iodic acid alone met with negative results. Thus, a single drop of a decinormal solution of iodine, made as usual in potassium iodide, gave when added to 10^{cm^3} of decinormal iodic acid a distinctive color to chloroform. Similar results were obtained when the iodine was employed in aqueous solution in which there was no alkaline iodide. A few drops of an aqueous solution of iodine treated (in either order) with 10^{cm^3} of a saturated solution of potassium bicarbonate and 10^{cm^3} of decinormal iodic acid gave the same distinctive color to chloroform as came from the same amount of iodine in the absence of the iodic acid. So it appears that if in the system under consideration, reactions do occur between iodic acid and iodine to alter the amount of iodine recoverable, such action is not appreciable between small amounts of these materials. This, however, does not preclude the possibility of perceptible changes under the mass-action of a large amount of iodine.

The reactions of hydrochloric acid, and probably of hydrobromic acid, in the presence of varying amounts of iodic acid, iodine and iodide, as well as the reaction of the alkaline carbonate upon such mixtures are doubtless complex, more or less reversible, and dependent upon proportions and dilution. The tendency of the former reactions is toward the reduction of the molecule of iodic acid, and the formation of the chloride or bromide of iodine. Thus, Miss Roberts† demonstrated that a

* Roberts, this Journal, *xlvi*, 157. † Loc. cit.

solution of hydrochloric acid, so dilute that by itself it is without effect on iodic acid, acts upon a mixture of iodic acid with either free iodine or an iodide to form iodine monochloride. The action of the acid carbonate upon the iodine chloride or bromide may produce a salt of the oxy-acids and free iodine.

The practical effects, under the conditions of analysis, of the reaction between iodine, iodic acid and the halogen acids in presence of sulphuric acid, and of reactions which may occur upon neutralization by an acid carbonate, were studied in detail in a number of experiments.

TABLE I.
Effect of the Carbonate.

| [5 ^{cm} H ₂ SO ₄ (1:3). Total volume of liquid, 250 ^{cm} .] | | | | |
|---|--------------------------|---|------------------|----------------|
| | I (in KI) taken. grm. | KHCO ₃ in excess. cm ³ . | I found. grm. | Error. grm. |
| (1) | 0·0713 | very small | 0·0707 | 0·0006 — |
| (2) | 0·0715 | very small | 0·0710 | 0·0005 — |
| (3) | 0·0713 | 10 | 0·0710 | 0·0003 — |
| (4) | 0·0710 | 10 | 0·0706 | 0·0004 — |
| (5) | 0·0723 | 10 | 0·0717 | 0·0006 — |
| (6) | 0·0713 | 20 | 0·0709 | 0·0004 — |
| (7) | 0·0713 | 20 | 0·0709 | 0·0004 — |
| (8) | 0·3565 | very small | 0·3560 | 0·0005 — |
| (9) | 0·3568 | very small | 0·3561 | 0·0007 — |
| (10) | 0·3567 | 10 | 0·3563 | 0·0004 — |
| (11) | 0·3596 | 10 | 0·3588 | 0·0008 — |
| (12) | 0·3565 | 10 | 0·3665 | 0·0000 |
| (13) | 0·3572 | 20 | 0·3560 | 0·0012 — |
| (14) | 0·3567 | 20 | 0·3569 | 0·0002 + |

The preliminary experiments of Table I were made to bring out the effect of neutralizing with the acid carbonate and subsequently titrating with an alkaline arsenite a solution containing sulphuric acid and a considerable amount of free iodine. The danger of mechanical loss of iodine during the effervescence accompanying neutralization, as well as by spontaneous volatilization from the surface during the process of titration, was minimized by effecting the neutralization in the trapped Drexel washing-bottle to be described later, and making the titration in the same tall washing cylinder without transfer. To varying amounts of a recently standardized decinormal solution of iodine were added successively 5^{cm} of dilute sulphuric acid and varying amounts of potassium bicarbonate in excess of that necessary to neutralize the free acid, decinormal arsenious acid in slight excess of the iodine, 5^{cm} of starch emulsion; and decinormal iodine to coloration, the total volume of the liquid

being not greater than 250cm^3 . The results show plainly that while the loss, mechanical or otherwise, in the treatment of reasonably large amounts of fairly concentrated iodine is perceptible, it is still well within permissible limits (amounting to a little less than 0.0005 gm. in the mean), and obviously independent of the excess of the carbonate in the solution, and of the amount of free iodine present.

In the experiments of Table II the proposed process of analysis was tested upon potassium iodide taken by itself in varying amounts of a $\frac{1}{40}$ normal solution and carefully standardized by the method formerly elaborated in this laboratory.* The apparatus employed was a Drexel washing-bottle of 500cm^3 or 1000cm^3 capacity, according to requirements, with stop-cock and thistle-tube fused to the inlet tube and a Will and Varrentrapp absorption trap sealed to the outlet, as shown in the accompanying figure. The iodide for the test



was drawn from a burette into the bottle and carefully washed down, and potassium iodate in excess of the amount theoretically necessary (namely, 5cm^3 of a 0.5 per cent solution for every portion of 20cm^3 of the iodide solution), was added and the volume of the liquid was adjusted to the volume at which it was desired that the iodic and hydriodic acids should react. The stopper with the thistle-tube and trap was now placed on the bottle and the trap was half filled by means of a pipette with a 5 per cent solution of potassium iodide. Five centimeters of dilute ($1:3$) sulphuric acid were added through the thistle-tube and washed down; the stop-cock was closed, and the solution gently agitated, if necessary, to insure a complete separation of iodine. Potassium bicarbonate in saturated solution to an amount about 10cm^3 in excess of that required to neutralize 5cm^3 of dilute ($1:3$) sulphuric acid, was poured into the thistle-tube, and allowed to flow into the bottle slowly enough to avoid a too violent evolution of gas. The stop-cock was closed and the solution agitated by giving to the bottle a rotary motion, at the same time keeping the bottom pressed down upon the work-table, to prevent a possible splashing of the iodide out of the trap into the yet acid solution. When the neutralization of the solution had been completed, the bottle was shaken until the last trace of violet vapor was absorbed in the liquid. The greater part of the solution in the trap was then run back into the bottle, the stopper removed, and the tube and trap carefully washed, the washings being added to the bulk of the solution. Deci-

* Gooch and Browning: This Journal, xxxix, 188.

normal arsenious acid was introduced from a burette to the bleaching point, 5^{cm}³ of starch emulsion were added, and the solution was titrated back with decinormal iodine (usually only a few drops) to coloration.

TABLE II.
Effect of Dilution.

| | KI taken. gram. | KI found. gram. | Error. gram. | Approximate volume upon addition of H ₂ SO ₄ . cm ³ | Volume H ₂ SO ₄ (1:3) used. cm ³ |
|------|--------------------|--------------------|-----------------|---|--|
| (1) | 0.0772 | 0.0768 | 0.0004— | 150 | 5 |
| (2) | 0.0772 | 0.0765 | 0.0007— | " | " |
| (3) | 0.1544 | 0.1546 | 0.0002+ | " | " |
| (4) | 0.1544 | 0.1541 | 0.0003— | " | " |
| (5) | 0.3087 | 0.3090 | 0.0003+ | " | " |
| (6) | 0.3087 | 0.3088 | 0.0001+ | " | " |
| (7) | 0.3859 | 0.3864 | 0.0005+ | " | " |
| (8) | 0.3859 | 0.3860 | 0.0001+ | " | " |
| (9) | 0.0772 | 0.0754 | 0.0018— | 300 | 5 |
| (10) | 0.0772 | 0.0757 | 0.0015— | " | " |
| (11) | 0.1543 | 0.1532 | 0.0011— | " | " |
| (12) | 0.1544 | 0.1524 | 0.0020— | " | " |
| (13) | 0.0772 | 0.0744 | 0.0028— | 500 | 5 |
| (14) | 0.0772 | 0.0737 | 0.0035— | " | " |
| (15) | 0.1544 | 0.1521 | 0.0023— | " | " |
| (16) | 0.1544 | 0.1512 | 0.0032— | " | " |
| (17) | 0.3859 | 0.3827 | 0.0032— | " | " |
| (18) | 0.3859 | 0.3831 | 0.0028— | " | " |
| (19) | 0.0772 | 0.0744 | 0.0028— | 500 | 10 |
| (20) | 0.0772 | 0.0757 | 0.0015— | " | " |
| (21) | 0.3859 | 0.3828 | 0.0031— | " | " |
| (22) | 0.3859 | 0.3827 | 0.0032— | " | " |

Blank tests made upon a solution obtained by mixing the maximum amount of the iodate with 5^{cm}³ of dilute sulphuric acid (1:3), neutralizing as usual with potassium bicarbonate, adding the iodide from the trap and 5^{cm}³ of starch emulsion, showed that a single drop of iodine was invariably sufficient to bring out the starch blue. Occasionally it was found that the mixture, particularly when chlorides or bromides were present, of itself developed a trace of color, but by no means a reading tint. A correction of the one drop of iodine necessary to bring out the color reaction in the blanks, was applied uniformly in the analytical process.

The number of centimeters of decinormal arsenious acid required to bleach the free iodine, multiplied by 0.01383 (log. 2.140822) gives the number of grams of potassium iodide taken for analysis, being equivalent to five-sixths of the iodine liberated in the solution.

From these results it appears that the degree of dilution of the solution at the time when the mixed iodide and iodate are acidified has an important influence on the completeness of the reaction. Thus, the mean error of the determinations in which the volume at the time of the reaction did not exceed 150^{cm}³ was practically nothing, while the errors at volumes of 300^{cm}³ and 500^{cm}³ amounted to 0.0016 gram. and 0.0028 gram. respectively. It is obvious that the doubling of the amount of sulphuric acid used in acidifying does not increase the amount of iodine liberated at the highest dilution. The plain inference is that the interaction between the iodide and iodate should be brought about in a volume of liquid not much exceeding 150^{cm}³.

In the following series of experiments, recorded in Table III, the effect of the introduction of a chloride or bromide into the iodide (before the iodate is added) was studied. The volume of the liquid at the time of acidifying was fixed at 150^{cm}³, approximately, and 5^{cm}³ of the dilute sulphuric acid (1:3) were used. The mode of procedure was otherwise similar to that of the foregoing series.

TABLE III.

Effect of Chloride and Bromide.

| | KI taken. gram. | KI found. gram. | Error. gram. | NaCl taken. gram. | KBr taken. gram. |
|------|--------------------|--------------------|-----------------|----------------------|---------------------|
| (1) | 0.0772 | 0.0795 | 0.0023 + | 0.2 | -- |
| (2) | 0.0772 | 0.0784 | 0.0012 + | 0.2 | -- |
| (3) | 0.0771 | 0.0823 | 0.0052 + | 0.5 | -- |
| (4) | 0.0773 | 0.0819 | 0.0046 + | 0.5 | -- |
| (5) | 0.1544 | 0.1588 | 0.0044 + | 0.5 | -- |
| (6) | 0.1544 | 0.1590 | 0.0046 + | 0.5 | -- |
| (7) | 0.0772 | 0.0802 | 0.0030 + | -- | 0.2 |
| (8) | 0.0773 | 0.0853 | 0.0080 + | -- | 0.2 |
| (9) | 0.0772 | 0.0873 | 0.0101 + | -- | 0.5 |
| (10) | 0.0772 | 0.0861 | 0.0089 + | -- | 0.5 |
| (11) | 0.1544 | 0.1646 | 0.0102 + | -- | 0.5 |
| (12) | 0.1543 | 0.1626 | 0.0083 + | -- | 0.5 |

The influence of sodium chloride and potassium bromide in increasing the amount of iodine liberated is plain. The increase comes without doubt from the iodate, and is doubtless due to the formation of iodine chloride or bromide, during the

acidifying, by the interaction of the free iodine, the iodic acid, and the hydrochloric or hydrobromic acid, according to the reactions previously discussed. It is plain, therefore, that the value of the process in the determination of iodine in an iodide is restricted of necessity to those cases in which it is known that chlorides or bromides are not present to any considerable extent. For determining the standard of a solution of nearly pure potassium iodide, employed in so many laboratory processes, it should find useful application.

TABLE IV.
Analysis of Pure Potassium Iodide.

| | KI taken. gram. | KI found gram. | Error. gram. |
|------|--------------------|-------------------|-----------------|
| (1) | 0·0814 | 0·0816 | 0·0002 + |
| (2) | 0·0814 | 0·0813 | 0·0001 — |
| (3) | 0·0814 | 0·0805 | 0 0009 — |
| (4) | 0·0815 | 0·0809 | 0·0006 — |
| (5) | 0·0814 | 0·0808 | 0·0006 — |
| (6) | 0·0814 | 0·0806 | 0·0008 — |
| (7) | 0·0814 | 0·0812 | 0·0002 — |
| (8) | 0·1628 | 0·1624 | 0·0004 — |
| (9) | 0·1628 | 0·1617 | 0·0011 — |
| (10) | 0·1628 | 0·1621 | 0·0007 — |
| (11) | 0·1628 | 0·1619 | 0·0009 — |
| (12) | 0·1628 | 0·1624 | 0·0004 — |
| (13) | 0·1628 | 0·1621 | 0·0007 — |
| (14) | 0·1628 | 0·1626 | 0·0002 — |
| (15) | 0·2442 | 0·2451 | 0·0009 + |
| (16) | 0·2442 | 0·2442 | 0·0000 |
| (17) | 0·2442 | 0·2439 | 0·0003 — |
| (18) | 0·3256 | 0·3258 | 0·0002 + |
| (19) | 0·3256 | 0·3256 | 0·0000 |
| (20) | 0·3256 | 0·3258 | 0·0002 + |
| (21) | 0·3256 | 0·3272 | 0·0016 + |
| (22) | 0·3256 | 0·3256 | 0·0000 |
| (23) | 0·4071 | 0·4076 | 0·0005 + |
| (24) | 0·4071 | 0·4080 | 0·0009 + |
| (25) | 0·4071 | 0·4073 | 0·0002 + |

In Table IV are comprised a number of experiments made exactly like those which seemed to give the best results in the series of Table II. The iodide and an excess of iodate (5 cm^3 of the 0·5 per cent solution to every 20 cm^3 of $\frac{N}{40}$ iodide) were made to interact in a volume of about 150 cm^3 , 5 cm^3 of sulphuric acid (1 : 3), were used to bring about the reaction, 10 cm^3 of potassium bicarbonate were added after the neutralization of the sulphuric

ric acid was complete, and the free iodine was estimated by titrating decinormal arsenious acid, the manipulation being like that previously described in detail.

The average result of a series of several determinations in which a great excess (0.1 gm.) of potassium iodate was used, proved to be practically identical with that of a similar series in which only a small excess of the iodate was employed, so that it appears to be unnecessary in any practical work to restrict the amount of iodate below the amount necessary to decompose the maximum quantity of potassium iodide which we have handled, namely, 0.4 gm.

It appears that for the estimation of iodine in a soluble iodide free from notable amounts of chlorides or bromides, this method, depending as it does upon a single standard solution, is simple, fairly accurate, and rapid.

ART. XXVIII.—*The Granitic Rocks of the Pyramid Peak District, Sierra Nevada, California*; by WALDEMAR LINDGREN.

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It has long been known that the summit region of the Sierra Nevada is occupied by an enormous mass of granitic rocks, and that a large part of it consists of granodiorite, a rock intermediate between a granite and a diorite, but no detailed maps have thus far been made of the granitic areas. An opportunity was offered for the study of these granitic rocks during the survey of Pyramid Peak atlas sheet, which was undertaken in the summer of 1894 by the writer, assisted by Mr. H. C. Hoover. The results are shown in the accompanying map (p. 302), compiled from the Pyramid Peak folio now in press.

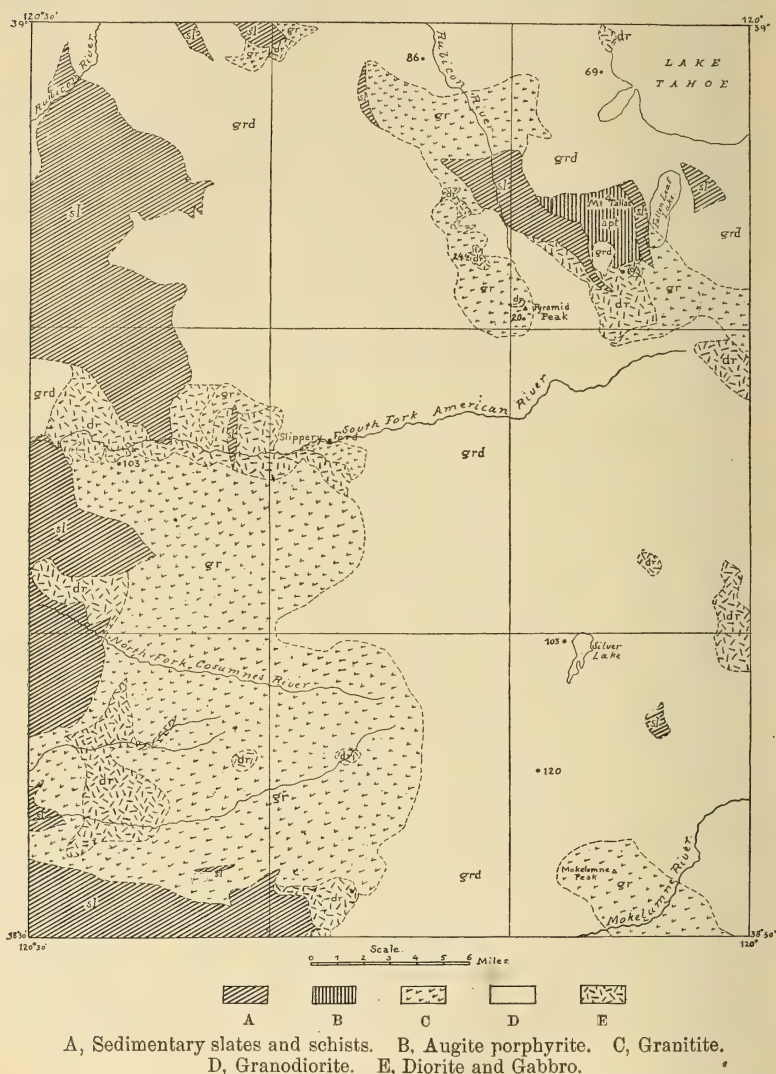
The region embraces half a degree of latitude by half a degree of longitude, and contains 927 square miles. The southern end of Lake Tahoe falls within the northern corner, and the main divide of the mountain range runs near the eastern boundary of the sheet. While the western part is occupied by an approximate plateau deeply trenched by canyons and gulches, the crest of the Sierra Nevada rises in the eastern part to lofty snow-capped mountains. The drainage of the western part is toward the Sacramento and San Joaquin rivers, while the drainage toward Lake Tahoe eventually finds its way to the deserts of the Great Basin.

The older bed-rock series consists of slates, schists and granitic rocks. These are extensively covered by Tertiary eruptives, andesite, rhyolite and basalt, which have not been indicated in the map accompanying this paper. To the west the slates, schists and accompanying basic eruptive rocks continue down to the foothills of the range and contain several small masses of granitic rocks. Toward the east the latter continue over to the eastern escarpment of the Sierra Nevada. The range in this vicinity contains two summit-ridges. The westerly, dividing the Pacific from the Great Basin, is found on this sheet, while the easterly summit divides the drainage flowing into Lake Tahoe from that running into the Carson River.

The Sedimentary Areas.

No fossils have been found in any of the sedimentary rocks of the bed-rock series within the limit of this sheet, and the age assigned is in all cases tentative only. The determinations are, however, based upon a comparison with formations of

approximately known age in adjoining areas, and they therefore possess a strong degree of probability.



Under the name of the Calaveras formation the beds of Paleozoic age have been comprised which cannot at present be further subdivided. The larger part of them probably belong to the lower or middle Carboniferous. To this formation all of the sedimentary rocks along the western boundary of the

sheet belong. The sedimentary rocks are separated from the granite by an extremely irregular contact line. The bays of granitic rocks reach far into the schists and slates, and all along this contact the sedimentary rocks have been subjected to an intense contact metamorphism, but of fusion or absorption there is absolutely no evidence.

The whole of the Calaveras formation on the eastern part of the Placerville sheet and on this sheet has a pronounced siliceous character; it consists of altered sandstones, grading into quartzite, and clay slates grading into micaceous schists. The cause of the metamorphism is partly of a regional character and caused by dynamic movements affecting a large part of the Sierra Nevada, chiefly prior to the great granitic intrusions, partly of a local character, and caused by the heat and the emanations from the intrusion of enormous masses of granitic magmas. While the latter metamorphism is superimposed upon the former, and the phenomena resulting from each not always easy to discriminate, it is clearly seen that the extremely altered sediments are found only at the contacts with the granitic rocks, and that the degree of metamorphism gradually decreases away from it. The contact zones are here very wide, typical contact metamorphic rocks often being found two miles from the contacts, or even more in case of projecting masses of sedimentary rocks surrounded on all sides by granite. It does not appear probable that any of these rocks are old, pre-Carboniferous or Archean schists.

Less altered rocks, the elastic character of which is clearly apparent, occur at a few places near the western border of the sheet. They are principally dark clay-slates and quartzitic rocks, which under the microscope show their fragmental origin. Thus on Silver Creek, near the western boundary of the sheet, on Sly Park Creek, at Fort Grizzly and southeast of Tar's Sawmill. But the larger part of the Calaveras formation in this sheet is occupied by the contact metamorphic schists. In places especially exposed to the action of the granitic magma, the rock is converted to normal, medium-grained gneiss or mica-schist, and at these places the contacts with the granite, usually sharp, are liable to become indistinct. Somewhat farther away the schists are finer-grained, generally of a brownish color, from the biotite contained, or of a silvery lustre caused by scales of muscovite on the planes of schistosity. The surface is frequently knotty, changing to normal "Knotenschiefer." They often carry andalusite, characteristic for contact rocks, in well-developed crystals, and such rocks may be found more than one mile distant from the contact.

Excellent exposures are found in the deep canyons of Silver Creek, Camp Creek and the north fork of the Cosumnes,

but they are accessible only with difficulty. The schistosity is indicated on the outcrop by lines, straight on the whole, but delicately wavy in detail; heavy benches alternate with streaks, in which the lamination is very fine. Nodules and nests of apparently segregated quartz are common. On the ridges and slopes satisfactory outcrops are rarely seen, as the rock here weathers to a dark-red soil.

A part of the area in the southwestern corner, is also intensely altered; micaceous schists and a striped green and white schist, consisting of pyroxene, quartz, feldspar and wollastonite, evidently a product of contact metamorphic action on limestone, appear in this vicinity.

The stratification can only rarely be observed beyond doubt, as for instance where quartzite and black clay-slate alternate, but it is probable that in most cases the stratification approximately coincides with the superimposed schistosity. In the northern area the strike of the schistosity is generally due north and the dip either about vertical or westward at a steep angle, this being contrary to the general rule further down the slope. South of the south fork of the American River the strike is more irregular, but generally east-west, while the dip is always within 20° of the perpendicular and usually to the north. Comparing with the S.E. part of Placerville sheet and the N.E. part of Jackson sheet, it will be seen that the series in these regions also has an abnormal east-west strike; the cause may possibly be sought in the mechanics of the intrusion, the slates in this vicinity being especially torn up by deeply incised bays of granitic rock. Horizontal and inclined joints also traverse the schists, separating them into rhomboidal fragments. The contact of the schists with the granitic rock is usually best defined where that line runs parallel to the schistosity. Wherever the contact cuts across the strike a stronger metamorphism, accompanied by a feathering out of the schists and by an injection of granitic magma, is often noted. The cleavage of the schists has not been produced by the pressure of the intruding magma; it existed before the granitic irruption.

A few isolated areas of schists, quartzites and highly-altered tuffs referred to the Jura-trias are scattered on both sides of the crest in the northern part of the area of the Pyramid Peak sheet. One of the principal reasons for assigning them, with doubt, however, to the Jura-trias is their position in the continuation of strata known to be of that age in the area of the Truckee sheet adjoining northward; another is that the principal mass, near Mount Tallac, is intimately connected with large masses of dark-green diabase-porphyrity and porphyryite tuff, which is characteristic of the Jura-trias at Sailor Canyon (Colfax sheet) and northward. The color of the outcrops of

these schist areas is usually reddish brown, contrasting strongly with the light-gray granodiorite.

The two small areas at the northern boundary consist of quartzite and black slate, the latter altered near the contacts to gneissoid micaceous schist; the contacts are usually sharp, extremely so where the road crosses the western area. At other places, as for instance, on the west side of Loon Lake, the contact is very unsatisfactory, the reddish granitic outcrops being everywhere mixed with schistose fragments.

The long and narrow area west of Tells Peak is strongly metamorphosed and composed of gneissoid schists, quartzites and mica-chlorite-andalusite schists.

The largest area of supposed Jura-trias lies in Rockbound Valley between Mount Tallac and the Pyramid Peak Range; it has a roughly triangular form and is distinguished by outcrops of dull gray or brown color. The rocks consist of a series of clearly stratified black slates and white quartzitic rocks; beautifully banded hard rocks, dark-gray and white, also occur in Rockbound Valley. The normal strike appears to be N.N.W., with a dip of about 45° to the east; the schistosity is not prominent. In the western point of the area the rocks are disturbed and dip in different directions. In the vicinity of Suzy Lake white quartzitic rocks crop, less clearly stratified, often indeed appearing massive. The microscope shows that the banded rocks from Rockbound Valley and in the Suzy Lake region are porphyrite tuffs, probably deposited contemporaneously with the eruption of the large porphyrite mass of Mount Tallac. Dikes of typical diabase porphyrite were noted on the west shore of Suzy Lake; on the western slope of Rockbound Valley uralite-porphyrates appear which would seem to lie conformably in the sedimentary series and are made somewhat schistose by pressure.

The Granitic Rocks.

The granitic rocks exhibit a rather unexpected variety in composition and structure. They include granites, aplites, granodiorites, diorites, and gabbro, by far the largest areas being, however, occupied by the granodiorite. The structure is always massive, a well defined schistosity being nowhere observed. Joints are frequent, however, and near the summit the rocks are intersected by extensive fissure systems.

Granite.—A normal biotite-granite or granitite occupies several large areas along the Pyramid Peak Range at Echo Lake, at Mokelumne Peak, and about the headwaters of the Cosumnes River. Its outcrops are generally distinguished by a light-yellowish or reddish color, due to the sesquioxide of iron contained in the orthoclase. It is harder and of a firmer texture

than the granodiorite, and its areas include the highest and roughest ridges in the region. For the same reason boulders and cobbles of granite are much more abundant than those of granodiorite. While it varies somewhat in appearance and constitution, yet it is a typical granite. The rock is coarse-grained and has often a decided tendency towards a rough porphyritic structure. The orthoclase appears as large grains and imperfect prisms of reddish gray color up to two or even three centimeters long; the quartz is very prominent in dark-gray rounded grains up to one centimeter in diameter, while the black mica and smaller quartz and feldspar grains lie between these larger constituents. Hornblende occurs only rarely; when it appears plagioclase usually also enters into the composition, and transition-forms to granodiorite result.

TABLE OF ANALYSES OF GRANITIC ROCKS.

| | <i>Analyst: Mr. Geo. Steiger.</i> | | | | | | | | |
|--------------------------------------|-----------------------------------|-------|--------|-------|-------|-------|-------|-------|-------|
| | I | II | III | IV | V | VI | VII | VIII | IX |
| SiO ₂ | 77.68 | 72.95 | 67.45 | 68.13 | 67.14 | 68.32 | 65.88 | 51.47 | 57.11 |
| TiO ₂ | .14 | | .58 | | | | | | |
| Al ₂ O ₃ | 11.81 | | 15.51 | | | | | | |
| Fe ₂ O ₃ | .72 | | 1.76 | | | | | | |
| FeO..... | .51 | | 2.21 | | | | | | |
| MnO..... | trace | | | | | | | | |
| CaO..... | .72 | 1.16 | 3.60 | 3.51 | 4.07 | 3.21 | 4.11 | 10.18 | 5.32 |
| MgO..... | .18 | | 1.10 | | | | | | |
| K ₂ O..... | 5.00 | 5.43 | 3.66 | 3.58 | 2.70 | 3.37 | 2.88 | 1.08 | 4.11 |
| Na ₂ O..... | 2.96 | 3.74 | 3.47 | 3.13 | 3.09 | 2.51 | 2.41 | 2.86 | 3.06 |
| Water 100— | .04 | | .14 | | | | | | |
| Water 100+ | .27 | | .63 | | | | | | |
| P ₂ O ₅ | .10 | | .12 | | | | | | |
| | 100.13 | | 100.25 | | | | | | |

- I. 164 Pyramid Peak collection; granite: Placerville Ditch, $\frac{1}{8}$ mile north of Ditch-camp 7. Lat. $38^{\circ} 45' 5''$; Long. $120^{\circ} 36' 1''$.
- II. 20 Pyramid Peak collection; granite; south side Pyramid Peak, 1,200 feet below summit. Lat. $38^{\circ} 50' 2''$; Long. $120^{\circ} 9' 5''$.
- III. 103 Pyramid Peak collection; granodiorite; road, $\frac{1}{4}$ mile west of Silver Lake House. Lat. $38^{\circ} 39' 8''$; Long. $120^{\circ} 7' 7''$.
- IV. 69 Pyramid Peak collection; granodiorite; trail Emerald Bay to Rubicon Point, $1\frac{1}{2}$ mile south of latter. Lat. $38^{\circ} 48' 6''$; Long. $120^{\circ} 6' 3''$.
- V. 86 Pyramid Peak collection: granodiorite; 1 mile E.S.E. of Rockbound Lake. Lat. $38^{\circ} 58' 8''$; Long. $120^{\circ} 13' 7''$.
- VI. 120 Pyramid Peak collection; granodiorite; Big Mud Lake bears N. 30° W. and is $1\frac{1}{2}$ mile distant. Lat. $38^{\circ} 35' 6''$; Long. $120^{\circ} 9''$.

- VII. 177 Pyramid Peak collection; granodiorite; Meek's Creek, 2 miles up from mouth at Lake Tahoe. Lat. $39^{\circ} 0' 8''$; Long. $120^{\circ} 9'$.
- VIII. 24 Pyramid Peak collection; diorite; Pyramid Peak bears S. 50° E. and is 3 miles distant. Head of Blakeley Creek. Lat. $38^{\circ} 52' 3''$; Long. $120^{\circ} 12'$.
- IX. 93 Pyramid Peak collection; Glen Alpine Spring bear N. 40° W. and is $\frac{3}{4}$ mile distant. Lat. $38^{\circ} 51' 9''$; Long. $120^{\circ} 5' 2''$.

Under I in the table of analyses is given one of these granites of an unusually fresh type. It is a light-gray, hard, granular rock with an approximation to a porphyritic habit. Macroscopically are noted large quartz grains up to five millimeters in diameter, large grains and imperfect prisms of feldspar up to ten millimeters in length. Between these larger grains lie the remaining feldspar-quartz mass with somewhat finer grain. Biotite in foils up to three millimeters in diameter are scattered through the rock. Microscopically, the structure is almost allotriomorphic, the rock being principally made up of large, irregular and very interlocking grains of microcline, microperthite, and quartz. In the microcline lie imbedded smaller grains and prisms of an acid plagioclase, as well as some quartz. Between the larger grains lie in places aggregates of quartz, microcline, albite, and oligoclase, also with interlocking structure. Biotite is sparingly present. The analysis may be calculated as follows:

| | | Per Cent. |
|---|-------|-----------|
| SiO ₂ | 18.23 | |
| Al ₂ O ₃ | 5.18 | |
| K ₂ O | 4.76 | |
| | <hr/> | |
| K Al Si ₃ O ₈ | | 28.17 |
| SiO ₂ | 17.24 | |
| Al ₂ O ₃ | 4.89 | |
| Na ₂ O | 2.96 | |
| | <hr/> | |
| Na Al Si ₃ O ₈ | | 25.09 |
| SiO ₂ | 1.05 | |
| Al ₂ O ₃ | .93 | |
| CaO | .49 | |
| | <hr/> | |
| Ca Al ₂ Si ₂ O ₈ | | 2.47 |
| P ₂ O ₅ | .10 | |
| CaO | .13 | |
| Cl | .02 | |
| | <hr/> | |
| Apatite | | .25 |

| | | |
|------------------------|-----|--------|
| TiO ₂ ----- | ·14 | |
| SiO ₂ ----- | ·11 | |
| CaO ----- | ·10 | |
| <hr/> | | |
| Titanite ----- | | ·35 |
| Biotite ----- | | 3·10 |
| Magnetite ----- | | ·61 |
| Quartz ----- | | 39·80 |
| Water ----- | | ·31 |
| | | <hr/> |
| | | 100·15 |

From the total amount of potash 0·24 was tentatively subtracted for the biotite. The total lime, after subtraction of amount needed for titanite, was counted to CaAl₂Si₂O₈; the total soda as NaAlSi₃O₈. On basis of remaining Al₂O₃ a portion of the silica was referred to the biotite and half the amount of iron oxide and sesquioxide subtracted as magnetite.

There remains then for the biotite:

| | | |
|--------------------------------------|------|--------|
| SiO ₂ ----- | 1·25 | 40·32 |
| Al ₂ O ₃ ----- | ·81 | 26·13 |
| Fe ₂ O ₃ ----- | ·62 | 20·00 |
| FeO ----- | | |
| MgO ----- | ·18 | 5·81 |
| K ₂ O ----- | ·24 | 7·74 |
| <hr/> | | <hr/> |
| 3·10 | | 100·00 |

This corresponds fairly well with a normal biotite.

A specimen from the south side of Pyramid Peak was subjected to a partial analysis (II), which shows it to be of practically the same composition as (I), though a little more of the anorthite molecule is present. The granite is on the whole very constant in mineral composition and it is believed that these analyses well indicate its average composition.

Granodiorite.*—As mentioned before, the granodiorite is the prevailing rock, occupying a broad belt extending across the whole area from north to south. It is of a crumbling nature, falling an easy prey to the destructive forces of weathering and

* The name of granodiorite was first proposed by Messrs. G. F. Becker, H. W. Turner and W. Lindgren in 1892. References to the rock may be found in the following places:

Geologic Atlas of the U. S., Folios 3, 5, 11, 18, 29.

W. Lindgren: The Auriferous Veins of Meadow Lake, this Journal, III, vol. xlv, p. 201, 1893; U. S. Geol. Survey, 14th Ann. Rep., pt. 2, p. 243; U. S. Geol. Survey, 17th Ann. Rept., pt. 1, p. 35.

H. W. Turner: U. S. Geol. Survey, 14th Ann. Rept., p. 478; U. S. Geol. Survey, 17th Ann. Rept., pt. 1, p. 724.

erosion. The outcrops are of rounded form, often weathering into huge detached boulders; the color is very light gray. The granodiorite is a medium to coarse-grained rock, the average diameter of the grain being 2 to 3 millimeters. The grayish quartz and white feldspar grains are of about equal size. The quartz is decidedly less prominent than in the granite, and the feldspar does not reach the dimensions attained in the latter rock. Black mica and hornblende are usually present in about equal quantities. The foils of the former reach 2 or 3 millimeters in diameter, while the hornblende is roughly prismatic, the crystals sometimes attaining 1 centimeter in length. By reason of this development of the hornblende, a somewhat porphyritic aspect may occasionally be obtained. Titanite is nearly always present in small isolated brownish grains. A little magnetite is also a constant accessory mineral. The appearance and composition of the rock is very constant over large areas, with only small variations in grain and in the quantity of hornblende and biotite. In a few places the quantity of hornblende diminishes and the rock then assumes a habit more similar to that of granite; thus, for instance, at Buck Island Lake, between Rubicon Peak and Rubicon Point and in the area east of Fallen Leaf Lake. Microscopical and chemical investigation shows the rock at this point to be a granodiorite, though rather rich in orthoclase.

Analysis III shows the composition of a typical granodiorite from the northwestern shore of Silver Lake. It is a light-gray granular rock composed of white or yellowish feldspar in grains and imperfect prisms, grayish quartz, biotite foils up to 1 millimeter in diameter, and a rather abundant dark-green hornblende in well-defined stout prisms up to 8 millimeters in length. Grains of brown titanite are also present.

The microscope shows the structure typical for granodiorites: Very plentiful, roughly idiomorphic prismatic crystals of an acid plagioclase, sharply outlined foils of yellowish brown biotite partly decomposed into chlorite, and grains of imperfect prisms of ordinary brownish green hornblende, accompanied by a few grains of magnetite. These constituents are cemented by anhedral quartz, orthoclase, and a little microcline. Titanite occurs in small grains enclosed in biotite. On the borders of the plagioclase and orthoclase a little micropegmatite often occurs. Some slight evidences of crushing are present in this rock, though such phenomena are in general very rare in the granodiorites.

As neither the hornblende nor the biotite has been analyzed, it is clear that no exact calculation of this analysis can be made. It is, however, possible to arrive at the approximate composition by means of the following calculation:

| | | Per Cent. |
|--|-------|-----------|
| SiO ₂ | 11.48 | |
| Al ₂ O ₃ | 3.27 | |
| K ₂ O | 3. | |
| <hr/> | | |
| KAISi ₃ O ₈ | | 17.75 |
| SiO ₂ | 20.20 | |
| Al ₂ O ₃ | 5.74 | |
| Na ₂ O | 3.47 | |
| <hr/> | | |
| NaAlSi ₃ O ₈ | | 29.41 |
| SiO ₂ | 5.14 | |
| Al ₂ O ₃ | 4.37 | |
| CaO | 2.40 | |
| <hr/> | | |
| CaAl ₂ Si ₂ O ₈ | | 11.91 |
| SiO ₂ | .42 | |
| TiO ₂ | .58 | |
| CaO | .40 | |
| <hr/> | | |
| Titanite | | 1.40 |
| P ₂ O ₅ | .12 | |
| CaO | .16 | |
| Cl | .02 | |
| <hr/> | | |
| Apatite | | .30 |
| Magnetite | | .84 |
| Hornblende and biotite | | 12.79 |
| Quartz | | 25.71 |
| <hr/> | | |
| | | 100.11 |

For the hornblende and biotite there remains:

| | |
|--------------------------------------|--------|
| SiO ₂ | (4.50) |
| Al ₂ O ₃ | 2.13 |
| Fe ₂ O ₃ | 1.13 |
| FeO | 2.00 |
| CaO | .64 |
| MgO | 1.10 |
| K ₂ O | .66 |
| H ₂ O | .63 |
| <hr/> | |
| | 12.79 |

The estimation is made in the following way: A small amount of potash and soda being first subtracted for the bio-

tite and hornblende, the remainder was calculated as orthoclase and albite. Further, 1.20 per cent lime was tentatively subtracted from the total as belonging to the hornblende, and 0.56 per cent for titanite and apatite, the remainder being calculated as anorthite. The amount of magnetite is estimated. From the remaining silica 4.50 per cent was subtracted to approximately correspond with the Al_2O_3 , and MgO available for biotite and hornblende.

The analysis is entirely typical for granodiorite and is extremely similar to the analyses of the granodiorite from Nevada City and Grass Valley, Nevada County.*

Under No. IV a partial analysis is recorded of a rock near the shore of Lake Tahoe, not far from the northern boundary line of the sheet. The rock is coarse granular, consisting chiefly of slightly reddish feldspar with much quartz. Hornblende and biotite are present in about equal quantities, but the hornblende occurs in small grains and prisms only. It was thought that this rock presented a certain similarity to the granite and it was therefore analyzed, but the figures obtained indicate it to be a normal granodiorite. The microscope shows a few large carlsbad twins of microcline and microperthite; an abundance of imperfect prisms of plagioclase imbedded in anhedral quartz, orthoclase, microcline and microperthite, the latter two often as Carlsbad twins; well-defined foils of biotite, a little hornblende and a few grains of titanite.

Analysis V shows the composition of a granodiorite from the valley of the Rubicon, 2 miles south of the northern boundary line of the sheet. Macroscopically the rock is very similar to IV. Under the microscope the same normal granodiorite structure is apparent. As in IV much of the potassium feldspar cementing the plagioclase prisms is microcline. The analysis indicates a normal granodiorite.

Analysis VI shows the composition of the granodiorite 6 miles south of Silver Lake in Bear River canyon. The rock is normal except for the fact that the quartz is rather prominent in grains up to 6 millimeters in diameter and that the biotite predominates over the hornblende.

Under the microscope it is evident that the cementing orthoclase and microcline are rather abundant, but the granodiorite structure is well-defined. Titanite is abundant. The analysis shows a closer approach to the granite than in any other of the rocks here examined; this is expressed in the high percentage of silica and potash, as well as in the relatively low percentage of lime. Still there is a wide gap between this rock and a normal granite.

Analysis VII shows the composition of the granodiorite of

* 17th Ann. Rept. U. S. Geol. Survey, pp. 38 and 42.

Meeks Creek, Truckee sheet, a few miles north of the northern boundary of the Pyramid Peak sheet. Both in appearance and composition the rock is a normal granodiorite.

Comparing the analytical and microscopical results with the field notes, it is clear that the granodiorite, as it appears in the High Sierra, is a rock of well-defined and fairly constant composition, structure, and appearance. It is neither a normal diorite, nor is it a granite; it is clearly an *intermediate* type, occupying a place between normal quartz-mica-diorite and quartz-monzonite (Brögger).^{*} All transitions toward diorite and, more rarely, toward granitite, may be found, but they are local and do not cover large areas, while the normal granodiorite is the prevailing rock of the Sierras. Comparing the type here described with the granodiorites of the many smaller areas enclosed in the slates on the western flank of the range, it can be stated that the latter as a rule approach more closely to the quartz-diorites, the percentage of lime being higher and the percentage of potash more often smaller than equal to that of soda. A few of these smaller granitic areas could, in fact, almost as well be indicated as quartz-mica-diorites. In the general habit, however, in the percentage of quartz, hornblende, and biotite, and in the constant presence of titanite, they are entirely similar to the granodiorites of the High Sierra. Microcline, not common in the granodiorites of the foothill region, occurs abundantly in those of the High Sierra.

Diorite and gabbro.—When the amount of hornblende and biotite in a granodiorite increases, it is usual to find the quartz and orthoclase relatively diminished in quantity and rock types more closely allied to normal diorites result. At the same time pyroxene frequently appears, and transitions into gabbro are formed. These more basic rocks in places form smaller areas enclosed in granodiorite or granite; more frequently they lie between the two rocks or on the contacts between granite or granodiorite and the schists. The rock in these areas is of a very variable structure and composition, ranging from a quartz-diorite to a gabbro, almost approaching a peridotite. The latter type is, however, rare. The normal diorite, such as occurs in the canyon of the south fork of the American River, is medium to coarse-grained, composed nearly entirely of hornblende and plagioclase. A little quartz, however, very frequently enters into the composition. Typical coarse-grained gabbros with large reddish gray basic feldspars and dark green

^{*} Though it is often difficult in practice to separate the normal quartz-mica-diorite from the granodiorite, it would seem suitable to restrict granodiorite to the following limits: SiO_2 59–69 per cent, Al_2O_3 14–17 per cent, Fe_2O_3 $1\frac{1}{2}$ – $2\frac{1}{4}$ per cent, FeO $1\frac{1}{2}$ – $4\frac{1}{4}$ per cent, CaO 3– $6\frac{1}{2}$ per cent, MgO 1– $2\frac{1}{2}$ per cent, K_2O 1– $3\frac{1}{2}$ Na_2O $2\frac{1}{2}$ – $4\frac{1}{2}$.

uralitized pyroxene occur near Round Top and to the west of Slippery Ford, and are connected with the diorites by abundant transitions.

Normal syenites have not been recognized, but intermediate rocks of the composition of monzonites may occur in places; it does not appear practicable, however, to separate them from the diorites.

A normal diorite from the western slope of the Pyramid Peak range was partially analyzed (VIII). The rock is granular, dark grayish green, the grains, averaging two millimeters in diameter, consist of feldspar, dark green hornblende and a little biotite. The plagioclase, which does not exceed andesine in basicity, occurs in imperfect short prisms, occasionally cemented by a little orthoclase. There is no quartz. The mica is in well-defined yellowish brown foils, often including small feldspar prisms. The hornblende occurs in irregular grains, but is sometime roughly idiomorphic. Small grains of titanite are present. The structure is typically hypidiomorphic. The composition is that of a normal diorite, indicated by the high percentage of lime and soda and small amount of potash. The hornblende must contain much lime.

Analysis IX shows the composition of one of the intermediate rocks, occurring in a diorite area a couple of miles south of Tallac Peak. It is a coarse-grained, dark rock made up chiefly of hornblende, a little biotite and feldspar. It carries a considerable amount of orthoclase, and its composition corresponds nearly exactly to the monzonite from Mulatto, analyzed by Lemberg.*

The relation and succession of the granitic rocks.—The contacts of the granodiorite with the granite are sometimes sharp, but more commonly much pegmatite, diorite and granite-porphyry occur on them, making them indistinct. In other places transition forms may be observed, such as at the northern end of Pyramid Peak granite area. Especially interesting are the exposures along the Pyramid Peak range. Wherever branches or bays of granodiorite reach into the granite a great variety of lighter or darker dioritic rocks make their appearance, in places bordering sharply against the granodiorite, at other times forming extremely graded transitions into it. Near the contacts of the schist areas it is quite common to find the granodiorite gradually growing darker and changing to diorites. The contacts between the granite and the diorite are usually sharper, and south of the south fork of the American River abundant well-defined dikes of granite occur in the diorite.

* W. C. Brögger: Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Süd Tyrol, p. 62.

There is no doubt that all of the granitic rocks are later than the altered sedimentary rocks and the augite-porphryite, but it must be confessed that in spite of good exposures the evidence as to the relative age of the granite, granodiorite, diorite and gabbro is not decisive, and even in some respects contradictory. There is some evidence, based on the general form of the Pyramid Peak granite area and the manner in which it includes the slate fragments, as well as on the occurrence in it of dikes of a rock allied to granodiorite, tending to show that the granite was intruded earlier than the granodiorite. On the other hand, it is unquestionably true that the granite of the southwestern corner sends out numerous dikes into the diorite of the south fork of the American River; this diorite again shows numerous local transitions to apparently normal granodiorite, so that if it be conceded that this diorite area is of approximately the same age as the main granodiorite mass, it would follow that the granite would be later than the granodiorite. The probability is that the intrusion both of the granite and of the granodiorite was accompanied by minor intrusions of acid and basic magmas, and that there are diorites, pegmatites and aplites of the age of the granodiorite and of that of the granite, the latter being the older rock; only on this supposition can the contradictory testimony be explained; the diorites of the canyon of the South Fork and in the smaller areas along the western boundary would then belong to the period of granitic intrusions, while those of Round Top and the Pyramid Peak range would belong to the granodiorite.

Washington, D. C., Jan., 1897.

ART. XXIX.—*Difference in the Climate of the Greenland and American sides of Davis' and Baffin's Bay* ;* by RALPH S. TARR.

Route followed.—During the summer of 1896, I made the journey along the Labrador and Baffin Land coasts, northward in the latter part of July and southward in early and middle September.† The period between these times was spent on the Greenland coast, the northernmost point visited being in lat. $74^{\circ} 15'$. Some features concerning the marked difference in climate on the two sides of the sea separating Greenland from the American land, apparently well known to Arctic voyagers, but new to me, have seemed to warrant brief statement.

Climate of American and Greenland sides.—On the northward trip a landing was made at the island of Turnavik, about in lat. 55° , on July 20. There extensive snow banks were found to be still lingering in the sheltered valleys, at points no more than one or two hundred feet above the sea level. Indeed several hundred miles to the south, on the west coast of Newfoundland, snow was seen. Later a landing was made in southern Baffin Land, on Hudson Straits, and here snow banks were also found. Nearly the entire distance traversed by the ship, from southern Labrador to the mouth of Cumberland Sound, one or two degrees south of the Arctic Circle, where we left the American coast, we met with floe ice, often so heavy that progress through it was slow and difficult. This was an unusual season, and hence the conditions were somewhat more severe than common. The ice is rarely so abundant at this season of the year. The presence of great floes, moving southward in the Labrador current, so chilled the air that the thermometer often stood in the thirties, and frequently descended to the freezing point. On July 30 snow fell in some quantity upon the ship, which then lay off Frobisher Bay.

On July 30 an unsuccessful attempt was made to enter Cumberland Sound, which was then, as often in this season of the year, completely shut in by the heavy ice floe. Not being

* It is a rather remarkable fact that the great bay which extends north to the Arctic circle, from the main Atlantic to Davis' Straits, should have been given no name. Baffin's Bay extends from Cape York to Davis' Straits at the Arctic circle; but no name is applied to the bay south of this. Because of the difficulty experienced in the attempt to write this article, on account of the absence of such a name, I would propose for the bay between Labrador and Greenland and south of Davis' Straits, the name *Davis' Bay* after the first navigator of these waters, who, in the year 1587, made the perilous voyage in a sailing vessel as far north as Upernavik.

† As a member of the Peary Greenland Expedition.

able to penetrate the ice, the ship left this bleak coast and crossed Davis' Straits to Disco island on the Greenland coast, going north four or five degrees. There we found a decided change in climatic conditions. The air was balmy, and although the highland portions of the mainland and island were ice-capped, and snow banks were seen in the protected valleys, the season was distinctly more advanced and more pleasant than on the American side two or three hundred miles southward. The flora was richer, insects were abundant, and everything betokened summer. Passing still farther northward to the Upper Nugsuak peninsula, in lat. $74^{\circ} 10'$, although the climate was somewhat more severe, it was distinctly farther advanced than on the American side which had been left a few days before, and which lay five or six hundred miles to the southward.

From August 7 to September 7, although by the latter date the night had begun, with the sun setting at about 7.30 in the evening, we were able to live comfortably in lat. $74^{\circ} 10'$ with no other protection than that of tents. During this time the lowest recorded temperature was 28° , which came at the coldest part of the night. The storms brought rain and not snow. Returning, we left Disco on September 11 after a beautiful, warm day. Snow had recently fallen upon the uplands, but many flowers were still in blossom near sea level. Coming southwards to the mouth of Cumberland Sound, our first view of the American land showed a snow-covered surface, and from this point to the north end of Newfoundland, freshly fallen snow was seen on the land.

Although we later found that the floe ice had disappeared from the Labrador coast, it still blocked a portion of the entrance to Cumberland Sound, and for sixty hours the ship was held a prisoner in this ice before we could pass into the Sound. After entering Cumberland Sound we encountered violent snow storms, and the fall of snow was sufficient to cover the surface of the land. Hence in this latitude, in the summer of 1896, snow fell on July 30 and on some day previous to September 13, the latter fall being sufficient to whiten the hills as seen from the sea.

Influence of Ocean Currents.—The causes for this difference between the climate of the two sides of a sea separated by only a few hundred miles in the broadest portions, are perhaps several, though the chief cause is to be found in the ocean currents. The icebergs and floes of the Arctic pass southward on the American side, and the cold ice-laden waters influence the climate of the neighboring land very perceptibly. On the Greenland side there is a current in an opposite direction, hence carrying warm water northward.

It is difficult to say how far the north-moving current

extends, and also how far from the land its influence is felt. I should say that the current does not probably reach far to sea; because if it did, the bergs and winter sea ice would not readily escape, and the Greenland coast would be ice-bound in summer, rather than ice-free as we found it.* There are some reasons for thinking that the north-moving current extends as far as the northern end of Melville Bay. The fact that great quantities of ice accumulate and remain there, rendering this bay notoriously difficult to navigate, seems to show that something interferes with the southward movement of the ice.

Pointing toward the same conclusion that the warm current reaches into Melville Bay, are the observations which were made from our camp at Wilcox Head, the point of the Upper Nugsuak peninsula which projects into Baffin's Bay near the southern end of Melville Bay. During two or three weeks encampment at this exposed point, it was noticed that the icebergs floated almost uniformly toward the north. It is true that this was a period during which south winds prevailed, but even when these did not blow, the bergs still moved northward. Moreover with but one hundred feet, or less, above the water, it seems improbable that the great ice masses which floated past our camp could have been driven so rapidly by mere wind action, particularly when the wind was not strong.

Influence of Winds.—There are two other reasons for climatic moderation on the Greenland coast; in the first place the winds from all directions, excepting the east, reach the shore from water, the temperature of which is well above the freezing point during the summer. The entire coast of this part of Greenland is then free from floe ice, and is encumbered only with scattered bergs and berg fragments. Hence on this coast the water is warmer than that on the opposite side of Baffin's Bay. On the one shore there is a cold ice-laden current, on the other a slowly moving drift of water *toward* the north. One might expect that the wind blowing from the ice cap of Greenland, the prevailing wind while we were there, would be cold; but the reverse is true. This wind, descending from great altitudes and passing over the surface of snow and ice, is really warmer than that from the sea, and at times it was

* Incidentally I would call attention to the fact that this clearing of the various forms of ice from the Greenland coast is usually made possible by the winds that blow from the ice cap. It is an interesting coincidence that the very cause for most of the ice gives rise to conditions which permit this to be carried away. From the cold highland area of inland Greenland, the dense air settles and blows outward, producing off-shore winds, which keep the fjords free of ice encumbrances; and at times, extending out from the coast, the wind drives this ice well to sea, where it comes under the influence of the south-moving currents, which I believe must exist not far from the Greenland shore.

noticeably warm, rapidly descending air. The explanation is no doubt the same as the explanation of the chinook and foehn winds.

Cause of difference in Glaciation.—On the Greenland side the land is mainly submerged beneath the great ice cap, with branches extending to the sea through the valleys. On the American side there are only a few isolated glaciers on Baffin Land, and none are known to exist in Labrador. On the American side the southernmost glacier is located on the southern side of Frobisher Bay in lat. 62°. It is evident that this difference in ice-covering is not due to the climate near the coast line, for a much greater development of glaciers is found on the side where the climate is more moderate. Possibly one of the causes for the difference is the greater humidity of the air that comes to Greenland after crossing over the waters of Baffin's and Davis' Bays; but the main cause for the difference is evidently the greater elevation of the land on the eastern side.

*Former Glaciation on the American side.**—Labrador and Baffin Land have been recently glaciated. So recent was this time of glaciation that at Turnavik Island, on the Labrador coast, glacial striæ still remain distinctly on the exposed rock-faces. The violent frost action on Baffin Land has in most cases removed the striæ; but the form of the hills, and the presence of erratics on the surface, show recent glaciation. Comparing the conditions seen here with those of New England, it seems certain that the glacier has left this northern region more recently than New England.

Changes in Level of Baffin Land.—Before the ice covered this land it was much higher than now. The evidence of this is as striking as that on the coast of Maine. The land valleys are in all stages of submergence; in Hudson Straits there are entirely submerged strike valleys, others into which the sea enters, and still others entirely above the sea level. The fjords, the nearly land-locked bays and sounds, and the land valleys extending beneath the sea, make this coast one of the most irregularly indented shores in the world. It is possible to navigate for fifty miles behind the land on the southern side of Cumberland Sound, being all the time behind hills which reach five hundred or a thousand feet above the sea.

It is practically certain that the glacial conditions came when this land was higher. When the ice disappeared the ancient highland was reduced in elevation, and the level of the hills was lowered three or four hundred feet below the surface of the sea, for beaches are found at this elevation, in various parts of

* Tarr, *Am. Geol.*, 1897, xix, 131 and 191.

Baffin Land.* Perhaps in this depression is found a potent cause for the disappearance of the ice sheets.

Now the American land is engaged in the reverse movement of uplift. It stood three hundred feet lower at a time so recent that the boulder beaches are distinctly visible, and the individual boulders scarcely injured by the action of the weather in this region of extremely violent frost work. Their surfaces bear lichens, but they are still rounded, and they lie directly on the surface, with scarcely any soil accumulation since they became a part of the dry land. Very recently this land was moving upward, for there are beaches directly above the present ones, and yet so closely connected with them that at first it seemed that they must be forming even now. This is in harmony with the evidence obtained by Dr. Bell on the shores of Hudson's Bay.

Relation of Changes in Level to Glaciation.—Elevation is a potent cause for glaciation. Baffin Land and Labrador have been glaciated in a recent period, during a time when the land stood a thousand feet or more above the present level. The ice of this period disappeared when the land was lowered, and possibly *because* it was lowered. Now the land is rising: at present the climate is so rigorous that even with the present elevation the conditions are nearly severe enough for glaciers to develop, and in some places they do actually exist. Even near the sea level the snow banks do not disappear before the first of August, and snow commences to fall in the autumn as early as the middle of September. So far as I can estimate from my short visit, it seems that there must be places not far above the sea level where even now the snow stays throughout the summer. A slight change in climate is all that is needed to increase the number of these, and to add to their area and depth until glaciers begin. The elevation needed for this increased rigor cannot be many hundred feet in the higher regions.

Such elevation, if widespread (and the recent uplifts have extended over a broad area), would remove another of the causes for moderation in this northern climate, namely the disappearance of some of the neighboring water: the recent uplift in Baffin Land has added a large amount of land to the former area, even though the elevation has been only about three hundred feet. This uplift has so decreased the depth of some of the bays and straits that an additional elevation of three hundred feet would very perceptibly reduce the amount of water both north and west of Labrador. This added land

* The question of the elevated beaches of Baffin Land is discussed by Mr. T. L. Watson in a paper published in the *Journ. of Geol.*, 1897, v, 17.

and decreased water area would increase the rigor of the climate.

The point which I wish chiefly to make is that the climatic conditions of Baffin Land and Labrador are wonderfully near those which produce glaciation. I would not predict that these lands are about to enter into a glaciated condition again, but it is safe to say that if the elevation now in progress continues, the time is not far distant when valley glaciers will again come in the Labrador peninsula and when those of Baffin Land will increase in extent, provided of course that there are no general changes of climate in progress, the nature of which we do not understand. From this condition of local glaciation to a general ice sheet, spreading over the land, the step is not great.

While upon this topic, and in conclusion, it may be pointed out that in addition to the moderateness of the summer climate of the Greenland coast, there is also a submergence of the land at present in progress. Topographical evidence of this is plain in the places which I visited, and the Danes have proved the point for at least some portions of the coast. Accompanying this subsidence, the Greenland glacier has recently withdrawn, at least from the land of the Upper Nugsuak peninsula, and the amount of withdrawal has been great indeed. Even now the ice-front at this point is moving backwards.

Is Greenland now passing through the stage of ice-withdrawal from which the American, Labrador and Baffin Lands have so recently escaped? and is there any relation between the down-sinking of Greenland and the uprising of Labrador and Baffin Land? Is the ice-withdrawal directly due to the land movement, and is the load of ice really the cause for the sinking which allows its withdrawal? that is, does the ice increase in area and extent with no other result than its own destruction by depressing the land, and hence removing the cause of supply? These questions very naturally arise and others even more speculative come to mind; but as their answer is not definitely at hand they may well be left as mere queries.

Ithaca, N. Y.

ART. XXX. — *On the Foramina perforating the Cranial Region of a Permian Reptile and on a Cast of its Brain Cavity*; by E. C. CASE.

DURING the spring of 1896 the author collected from the Middle Permian of Texas the nearly complete skeleton of a reptile (*Dimetrodon incisivus* Cope) belonging to the *Pelycosaurian* group of Cope's order *Theromora*. It has recently been shown* that the order *Theromora* has no existence and that the *Pelycosauria* are merely specialized *Rhynchocephalians* closely allied to *Palæohatteria*.

The cranial region in the specimen is especially well preserved and permits a close study of the different foramina. The bones are all in their natural relations and nearly free from distortion, so that the brain cavity when freed from its enclosed matrix showed its natural form. The occipital region closely resembles that of *Sphænodon*. The condyle is formed by the exoccipitals and basioccipital. The exoccipitals meet in the median line above, excluding the supraoccipital from any part in the foramen magnum. Laterally they join the expanded proximal ends of the paroccipitals. The supraoccipital is a triangular plate inclined forward as it ascends and joining by the base of the triangle the parietals above. Laterally it joins the paroccipitals and inferiorly the exoccipitals. The paroccipitals are expanded proximally, joining the supraoccipital and exoccipitals. Distally they are elongated outwards, backwards and downwards and join the greatly flattened quadrates. The lower edge of the proximal end is marked by a notch which, in union with similar notches in the basioccipital and petrosal form the fenestra ovalis. The paroccipitals remained free during life or until advanced age. This feature is found only in turtles and the young *Sphænodon*. It has been noticed in young lizards before leaving the egg.† The basioccipital forms the lower portion of the condyle and lies between the exoccipitals and paroccipitals. The lower surface is trough-like for its posterior half and supported a posterior extension of the basisphenoid. Laterally a slight notch forms the inner wall of the fenestra ovalis. Anterior to the horizontal, trough-like portion the inferior surface rises sharply; the angle thus formed is marked by a large foramen through which the hypophysis passes into the interior of the

* Baur and Case: On the Morphology of the Skull of the Pelycosauria, and the Origin of the Mammalia, *Anat. Anz.*, xiii, Nr. 4 and 5, 1897.

† Siebenrock, F.: Das Skelet der *Lacerta Simonyi* Steind. und der *Lacertiden* familie überhaupt; Sitzunberichten der kaiserl. Akademie der Wissenschaften in Wien. *Mathm. Naturwiss. Classe.*, ciii, Abth. 1, April, 1894.

basioccipital, fig. 3, *Hy. F.* The petrosals join the paroccipitals, exoccipitals and the basioccipital, but the sutures are not distinguishable. The lower part of the anterior edges were continued forward as long processes, the anterior inferior processes of Siebenrock.* These are partially destroyed in the specimen. A deep notch in the anterior edge of the petrosals just above the origin of these processes, the *incisura otosphenoidea* Sieb., marks the point of exit from the brain cavity of the fifth pair of nerves (trigeminus), fig. 3, 5. The superior end of the anterior edge is separated from the supraoccipital by a notch which is continued on the sides of the bone as a shallow, short groove. The posterior edge contributes the last portion to the walls of the fenestra ovalis.

The basisphenoid remained free. The posterior edge is greatly thickened vertically and its lower edge stood well away from the basioccipital. The otic region and the posterior edge of the basisphenoid were covered with a large mass of cartilage. The lower surface of the basisphenoid is excavated by a deep pit, fig. 2, *Eu*, which opens on the posterior as well as the inferior surface of the bone and divides the posterior into two parts. The upper edge of the posterior surface, forming the base of the pit, was continued backward as a spout-like process articulating with the lower surface of basioccipital. The anterior edge is extended forward as a parasphenoid rostrum originating between the short and stout pterygoid processes.

The foramina penetrating these bones are remarkably similar in position to those penetrating the same bones in *Sphaenodon*. The condylar foramen transmitting the twelfth pair (hypoglossus) penetrates the exoccipital just anterior to the edge of foramen magnum. Its outer end opens in a notch (the *incisura venæ jugularis* Sieb.) in the side of the exoccipital. A little below and further forward a second and much smaller foramen opens in the same notch; this may transmit either the ninth or tenth pair of nerves or a minor blood vessel. Passing forward the notch deepens and is very soon converted into a foramen by the adjacent portion of the paroccipital. This is the *foramen venæ jugularis* of Siebenrock and transmits the jugular vein and either the ninth or tenth nerves or both of them. In *Sphaenodon* the foramen transmits not only these but the twelfth pair as well, the nerves being separated from the vein by very thin walls of bone and may be separated from each other or have a common canal. The opening of the twelfth pair into the notch which forms the beginning of the

* Siebenrock, F.: Zur Osteologie des Hatteria-Kopfes *ibid.*, Bd. cii, Abth. 1, June, 1893.

jugular foramen is then very similar to the condition found in *Sphænodon*.

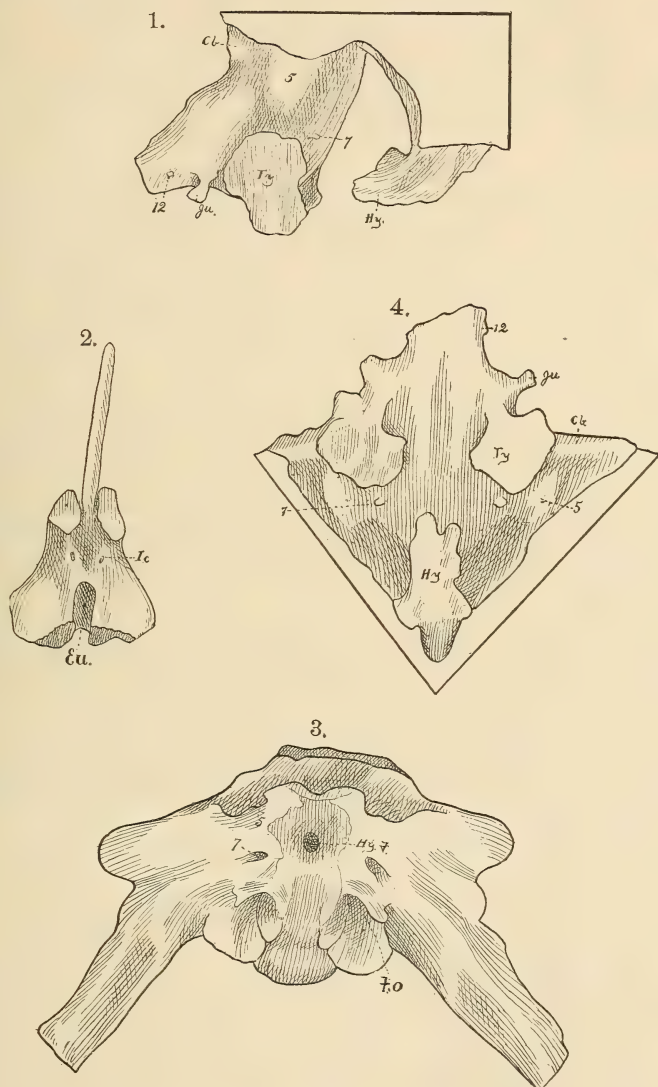


FIG. 1. Side view of a cast of the brain cavity.

FIG. 2. Lower view of the basisphenoid.

FIG. 3. Lower view of the cranial region.

FIG. 4. Lower view of the cast of the brain cavity.

5. The trigeminus nerve. *T.* The facial nerve. 12. The hypoglossus nerve. *Ju.* The jugular foramen. *Ty.* Cast of tympanic cavity. *Hy.* Hypophysis. *Hy. F.* Foramen penetrating base of basioccipital. *F. O.* Fenestra ovalis. *I. C.* Foramina for internal carotids. *Eu.* Opening of eustachian tubes. *Cb.* Cerebellum.

The fenestra ovalis, fig. 3, *F. O.*, is a single opening leading by a very short canal directly into the brain cavity, a character found in fishes and the amphibian *Menopoma* and existing imperfectly in some recent reptilia, as the turtles. The same thing is described by Cope as existing in another Permian reptile, from the same horizon as the present specimen, but belonging to a separate family, the *Diadectidæ*, and his order *Cotylosauria**.

The foramina for the seventh (facial) pair of nerves appear on the outer surface of the petrosal just anterior to the fenestra ovalis, fig. 3, 7. They are located relatively a little further back than in *Sphænodon*. On the inner face of the same bone the foramina appear at the side of the base of the brain cavity a little anterior to their external opening. They are located just anterior to a slight ridge which defines the limits of the tympanic cavity. In *Sphænodon* this is about the point of location of a foramen common to the seventh and eighth nerves, which, however, almost immediately divides, the posterior branch penetrating the inner wall of the tympanic cavity and leading the auditory nerve to the inner ear.

The foramen for the fifth (trigeminal) nerve is completed from the incisura otosphenoida by the membranous wall of the anterior portion of the brain case, as in *Sphænodon* and many lizards. Fig. 3, 5.

The deep pit excavating the lower surface of the basisphenoid is in all probability the lower opening of the eustachian tubes. In most reptilian forms the tubes pass into the pharynx in the neighborhood of the basioccipital-basisphenoid suture and anterior to the fenestra ovalis. In the crocodilia and the aglossal batrachians they have a common opening into the mouth. In the present form the tubes probably penetrated the large mass of cartilage covering the otic region and the posterior end of the basisphenoid and found a common opening in the deep pit described. It is difficult to imagine the use of such an extensive cavity in the basisphenoid, but in the *Teleosauria* an equally large cavity is found roofed over with bone. Anterior to this pit two foramina, fig. 2, *I. C.*, penetrate the lower surface of the basisphenoid bone and on its upper surface a large foramen appears just posterior to the origin of the presphenoid rostrum. Through the pair on the lower surface the internal carotid arteries enter the bone and through the upper it gains access to the brain cavity by way of the pituitary fossa. On either side of the single foramen a pair of small foramina carry branches of the internal carotid. All of

* Cope, E. D.: On the Structure of the Brain and Auditory Apparatus of a Theromorphous Reptile of the Permian Epoch, Proc. Am. Phil. Soc., vol. xxiii, 1885.

these foramina are very similar in position to the same ones in *Sphænodon*.

The cast of the brain cavity shows fairly well all parts posterior to the fifth pair of nerves, and the hypophysis anterior to them. As is well known, the brain in the reptilia does not fill the brain cavity but is supported by a mass of connective tissue carrying lymph and fat masses, so a cast of the brain cavity does not give an exact copy of the brain; however many points can be brought out by such a cast.

If the cast be held with the short terminal portion of the medulla horizontal, the lower surface pitches downward at a sharp angle to a point anterior to the tympanic region and then ascends as sharply to the point of origin of the hypophysis. The superior surface is horizontal and arched from side to side to a point over the tympanic cavity and there turns upward at an angle of 45° . The angle thus produced is marked by a low, narrow ridge running across the cast and marking the position on the brain of a narrow and elevated cerebellum, figs. 1 and 4 *Cb.*, such as occurs in *Sphænodon*. This region was probably the seat of a large amount of connective tissue and it is probable that the upper surface of the medulla descended at as sharp an angle as the lower. This would make still more marked the resemblance to *Sphænodon* and to the cast figured by Cope.* This sharp bend of the medulla downward is not found in other forms, though in the brain of *Chelonia* and some *lacertilia* a bend is apparent.

The sides of the medulla show most posteriorly the beginning of the twelfth nerves, figs. 1 and 4 (12), anterior to these the cast of the jugular foramen, figs. 1 and 4, *Ju.*, and finally the large casts of the tympanic cavity, figs. 1 and 4, *Ty.* The nature of the matrix and the cavities prevented the tympanic cavities being cleaned so that the semicircular canals could be determined, but it is probable that they were very similar to those described by Cope.

Anterior to the tympanic casts a sharp constriction marks the ridge defining the limits of the tympanic cavity and then a sharp outswelling the point of exit of the trigeminus nerve, figs. 1 and 4 (5). Near where these leave the body of the cast a small stub on each side marks the origin of the seventh pair, figs. 1 and 4 (7).

The hypophysis is the most interesting feature of the brain. Descending between the anterior inferior process of the petrosal and turning posteriorly, it occupies a small notch in the posterior edge of the upper surface of the basisphenoid and then passes directly into the body of the basioccipital through the foramen mentioned. In the *Crocodylia* a somewhat similar condition exists. The basisphenoid is excavated for a con-

* Baur and Case, loc. cit.

siderable extent to accommodate the hypophysis. This makes it probable that the excavation of the bone is merely a secondary character to make room for the hypophysis, for in the *Crocodylia* the basisphenoid takes a large part in the floor of the brain-cast, and in the present form it is pushed so far downward that it is excluded and the hypophysis encounters the basioccipital as soon as it turns toward the rear.

Marsh (* and †) has described in the family *Atlantosauridae* of his suborder *Sauropoda* of the *Dinosauria* a condition in which the pituitary cavity becomes a canal perforating the basisphenoid and opening into the pharyngeal cavity, considering it an embryonic character such as exists in the chick at the fifth day of incubation.*

If the hypophysis occupied the entire cavity in the basioccipital it extended back nearly as far as the tympanic region and much further back than in most reptilian forms. In *Sphenodon*, the *Crocodylia* and some amphibians it reaches well back, but not so far as in the present form.

Compared with *Sphenodon*, the specimen shows the following points of resemblance. The foramina for the blood vessels and nerves are almost identical in position and nature. The contour of the medulla and cerebellum was similar and the hypophysis extended far back. The only point of difference is the excavation of the basioccipital to receive the distal end of the hypophysis. The free communication of the tympanic cavity is a character which is found in many existing primitive forms and is of secondary importance.

The points here brought out confirm the close relationship of the *Pelycosauria* to the primitive *Rhynchocephalia* already asserted by Baur and Case.‡

* Marsh, O. C.: Principal Characters of American Dinosaurs, this Journal, vol. xxvi, August, 1883.

† Marsh, O. C.: American Dinosaurs, Sixteenth Annual Report U. S. Geol. Survey, 1896.

‡ Baur and Case: On the Morphology of the Skull of the Pelycosauria, and the Origin of the Mammalia, Anat. Anz., xiii, Nr. 4 and 5, 1897.

ART. XXXI.—*The Temperature and Ohmic Resistance of Gases during the Oscillatory Electric Discharge*; by JOHN TROWBRIDGE and THEODORE W. M. RICHARDS. With Plate VI.

IN our papers upon the spectra of argon and the multiple spectra of gases,* we have emphasized the importance of considering the electrical condition of the circuit in which is placed the Plücker tube containing the gas under examination. We have pointed anew to the fact that in general the continuous discharge of an accumulator produces one spectrum while the oscillatory discharge of a condenser produces another. In considering this question one is immediately struck by the fact that, although the gas acts as if it presented a resistance of several hundred thousand or even several million ohms to the current while under the influence of the continuous discharge, nevertheless this same tube allows oscillations which are wholly damped by a few hundred ohms to pass through it under the influence of a condenser. These considerations led us to measure the resistance of such a tube to the oscillatory discharge, and we found by means of a novel method that in fact *a mass of gas at low tension contained in a capillary tube may act as though it opposed a resistance of only five or six ohms to the spark of a large condenser.*

In order the more clearly to grasp the situation, the potential differences between the ends of the tube during a continuous discharge may well be considered first. A number of measurements of such potential differences have been made by Hittorf† and others, but it may be well to give two of the many series of measurements which we have made, in order to facilitate comparison with the discharge of the condenser through the same tubes. The tubes employed throughout this research were of the ordinary type devised by Plücker, consisting of two cylindrical bulbs separated by a capillary 1.3^{mm} in diameter and 7^{cm} long. The electrodes were of aluminum. Unless otherwise stated, all the experiments here recorded were made with tubes of exactly this shape and size; and most of the experiments were made with a single tube. The voltmeter used for measuring the potential differences was a Thomson electrostatic electrometer, and the current used was not much over a milliamperé.

As the voltmeter was only graduated to 1800 volts, the readings above that amount are merely approximations.

* This Journal, vol. iii, pp. 15 and 117, 1897.

† Wied. Ann., xx, 705.

Potential differences between electrodes of spectrum tube.

| Hydrogen. | | Nitrogen. | |
|-------------------|-----------|-------------------|------------|
| Pressure in mm | Voltage. | Pressure in mm | Voltage. |
| 7.0 | 2600 (?) | 8.5 | very high. |
| 6.0 | 2100 (?) | 5. | very high. |
| 4.0 | 1900 | 4. | 2600 (?) |
| 3.5 | 1500 | 3. | 2100 (?) |
| 2.0 | 1340 | 2.5 | 1750 |
| 1.5 | 1260 | 1.7 | 1600 |
| 1.25 | 1220 | 1.4 | 1410 |
| 1.15 | 1150 | 1.2 | 1340 |
| 1.00 | 1100 | 1.0 | 1180 |
| .70 | 1140 | 0.7 | 1140 |
| .50 | 1220 | 0.6 | 1080 |
| .13 | very high | 0.5 | 1040 |
| | | 0.3 | 980 |
| | | 0.25 | 1030 |
| | | 0.13 | 1700 |
| | | 0.06 | 2800 + (?) |

Each gas evidently has its minimum of potential difference, that of hydrogen lying at about 1 millimeter of pressure, and that of nitrogen at about 0.3 millimeter. These minima, as well as the total potential differences, are undoubtedly modified by the strength of the current; but the results given above are comparable with one another because they were all made under the same conditions. Hittorf found a minimum at about 0.35 millimeter for nitrogen, and he pointed out by means of his extra electrodes that the fall of potential was very irregular, the greater part of it residing at the cathode. His results have been confirmed by others, and Wood* has shown that the heat evolved at different parts of the tube follows the same irregularities as these potential differences.

Neglecting the factors of the potential difference which reside at the electrodes, the sum of which increase with the exhaustion of the tube, we find that according to Hittorf's results the resistance of the gas itself steadily diminishes as the exhaustion proceeds. For example, with a current of two milliamperes he found a fall of potential of about 120 volts between two parts of the middle of the tube eight centimeters apart, the tension of the nitrogen being 0.35 millimeter. When the current was about one milliampere and the tension of the gas was only about 0.001^{mm} the voltage sank to fifteen. These two figures correspond to resistance of 60,000 ohms and 15,000 ohms respectively, the resistance of the gas diminishing as the pressure is decreased. Of course we have no certainty as to how much of this opposition to the current is due to true

* Wied. Ann., lix, 238.

resistance and how much to a kind of polarization, but it is convenient for present purposes to count it all as resistance.

In any case this opposition, if maintained, is far too great to permit the passage of oscillations, even under the most favorable conditions. In order to prove that the opposition is not maintained, but is in fact broken down by the spark, it was only necessary to photograph the discharge with the help of a rapidly revolving mirror, after the method of Feddersen. Unfortunately the light in the tube itself is too faint for direct instantaneous photography: but the light of the spark between two cadmium electrodes in the same circuit is quite bright enough for the purpose, and of course any oscillations which crossed the spark gap must also go through the tube. Our next step was, therefore, to make a series of such photographs of a spark discharged through hydrogen, at first when the gas glowed with a white light and showed its many-line spectrum, and afterwards, when it exhibited the characteristic red tint and a spectrum of only four lines in the visible portion of the spectrum.

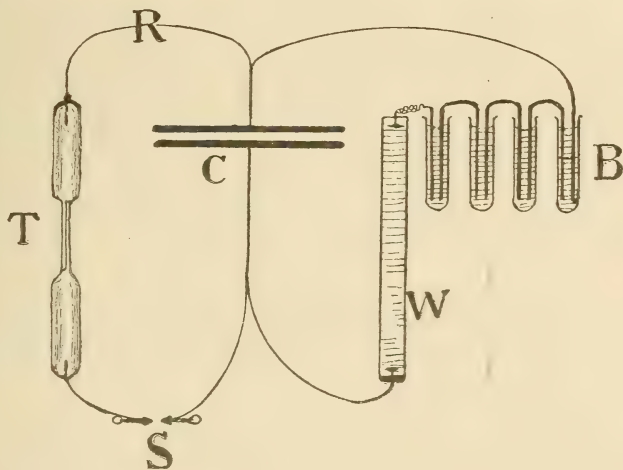


FIG. 1. B = Battery of 5,000 to 10,000 storage cells.
C = Condenser of 1,000 to 18,000 electrostatic units.
R = Small resistance to damp oscillations.
S = Spark gap between cadmium terminals.
T = Plücker tube containing gas.
W = Chief water resistance of 5 to 50 megohms.

In order to obtain the white light in the hydrogen tube, it was necessary to increase either the impedance or the resistance in the circuit containing the tube. With a definite very small amount of impedance we increased the resistance until the

red glow disappeared in the tube, and discovered, on developing the photographs which were obtained by means of the revolving mirror, that the discharge was non-oscillatory. When, however, the resistance in the condenser circuit was diminished, the red glow began to appear, and the photographs taken when all the resistance except the tube itself was removed showed that the discharge was oscillatory. This also was evident from the peculiar crackle of the spark, which Hertz remarked was essential in performing his experiments on electric waves. The apparatus used in this and subsequent experiments is sketched in the accompanying diagram (fig. 1). An examination of our photographs showed the interesting fact that there were in general not more than two or three complete oscillations; the remaining ones which could have been obtained from the given capacity and self-induction having been damped by the resistance of the gas. The question immediately arose: what is the resistance of the gas at the instant of the discharge? For if an idea of this can be obtained we can get an estimate of the amount of heat developed in the gas during each oscillation. A Thomson electrostatic voltmeter connected to the ends of the hydrogen tube indicated a difference of potential of over 1,800 volts, and this difference of potential could only be obtained by substituting for the Geissler tube a resistance of many thousand ohms. The indications, however, of this instrument in this case are of no value; for we discovered that a resistance of from ten to twenty ohms was sufficient to produce the same amount of damping which the gas exerted. The resistance of the gas, therefore, could not be greater than these amounts.* It is evident, therefore, why the voltmeter gives erroneous readings. On account of the inertia of the moving parts and the very short time of the discharge, it does not indicate the fall of potential through the small resistance of the tube during the instant when the discharge passes, but maintains an indication of a high difference of potential.

In order to apply systematically this new method of measuring resistance, our next step was to prepare a series of standards,—photographs of the oscillatory sparks of condensers of different sizes, damped by known resistances, which were substituted for the Geissler tube in the condenser circuit. In all these experiments, of course, the small resistance on the left hand side of the sketch was cut out by a suitable key. Three large Leyden jars, each 30 centimeters in diameter and 50 centimeters high, having a capacity of 6,000 electrostatic units apiece, were used either singly or together to act as the condenser; the waves generated by these large capacities were

* Damping of electrical oscillations, *Proc. Am. Acad.*, 1891.

much too long to interfere with one another upon so short a circuit. The resistances were wires of manganin 0.2^{mm} in diameter, stretched on both sides of long strips of thin vulcanite plate, the idea of this arrangement being to eliminate self-induction and yet to prevent the short-circuiting of the high potential. The spark gap usually consisted of cadmium terminals arranged in the focus of a revolving mirror driven very rapidly by means of a small electric motor. In a few cases zinc terminals were used, with no appreciable difference in the results (Rhigi*). The terminals were re-pointed from time to time and were always kept at a distance of 1.3 millimeters apart. With this apparatus the photographs of perhaps five hundred sparks were taken; and the results are recorded in the following table. As a general rule the spark containing the highest number of oscillations upon any plate was taken as the representative one.

The first column below records the resistance through which the discharge had to pass before reaching the spark gap, while the second, third and fourth record the number of half oscillations observed upon the photographs.

These figures correspond in general tendency with the less precise determinations made by Feddersen;† they show, as his determinations did, that the larger the capacity, the fewer the number of oscillations. This tendency is especially noticeable between two and ten ohms, the part of each curve which is most capable of accurate determination. While not perfectly regular, these curves manifestly furnish the means of measuring approximately any small resistance through which a spark, followed by as much as one-half of an oscillation, is able to pass.

Having now our scale of measurement, we substituted for our known resistances a Plücker tube attached to an admirable automatic Toepler air-pump (of Kiss, Budapest), as well as to receivers containing pure hydrogen and nitrogen. These gases could be delivered individually into the tube at any desired pressure. The bulbs of the pump, aggregating over a liter in volume, were always in communication with the Plücker tube, while the circuit was closed, so that the discharge took place under essentially constant pressure. The hydrogen was made electrolytically and purified by passing through a solution of potash, and over fused potash and phosphoric anhydride; the nitrogen was made by passing ammonia over an excess of heated cupric oxide, through much water, and over the same two driers as the hydrogen. The length of the spark gap remained always the same, excepting for the very lowest and the very highest pressures of gas, through which

* *Nuovo Cimento*, II, xvi, 97

† *Pogg. Ann.*, cxiii, p. 437.

Resistance Standards.

| Resistance Ohms. | Capacity=6,000. No. of half oscilla- tions. = | Capacity=12,000. No. of half oscilla- tions. = | Capacity=18,000. No. of half oscilla- tions. = |
|---------------------|---|--|--|
| 0 | | 37. | 32 |
| 1 | | 21. | 21 |
| 2 | 16. | 14. | 13 |
| 3 | 12. | 11. | 10 |
| 4 | 9.5 | 8.5 | 7 |
| 5 | 8. | 7. | 6 |
| 6 | 7.5 | 6. | 5 |
| 7 | 6.5 | 5. | 4 |
| 10 | 5 | 4 | 3 |
| 15 | 3 | 3 | |
| 20 | 2 | 2 | 1.7 |
| 30 | 1 | 1 | 1 |

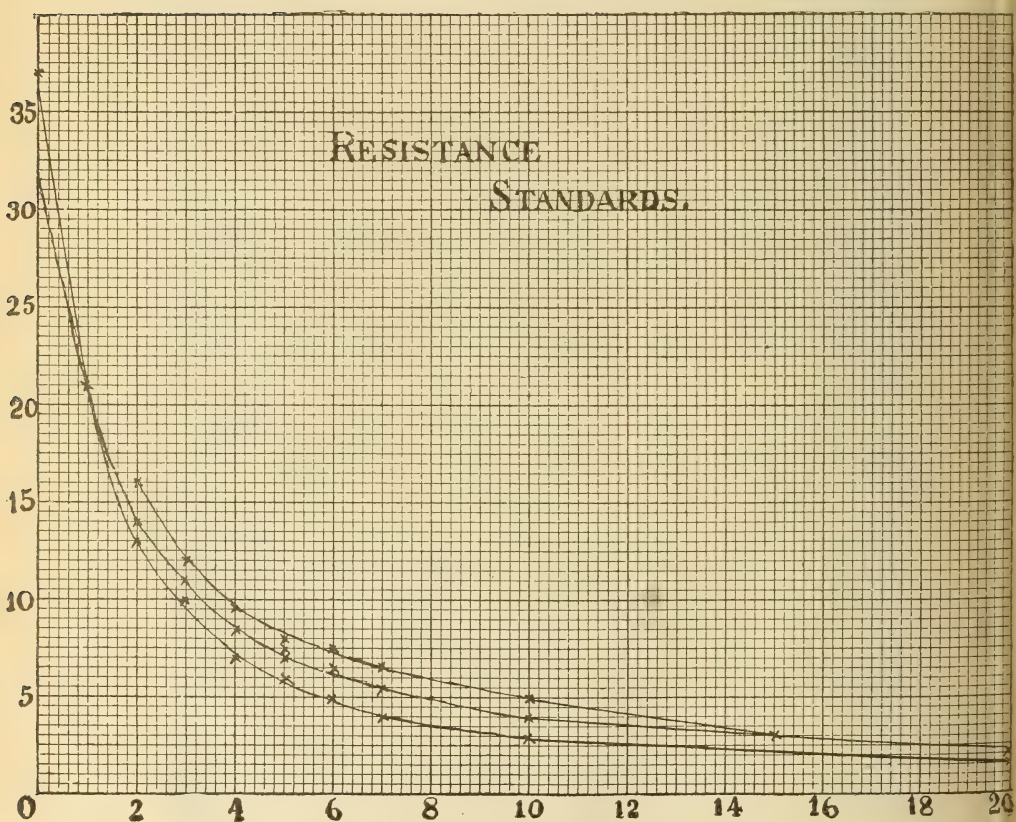


FIG. 2. Ohms are plotted horizontally.
Half oscillations are plotted vertically.

the electricity refused to pass unless the spark gap was narrowed.

In the first column of each table below is recorded the pressure of the gas, in the second, third and fourth are recorded the numbers of half oscillations obtained with the three different capacities respectively, while in the fifth, sixth, and seventh of these columns are to be found the resistances corresponding to these oscillations, each value being taken from its proper curve in fig. 2. In order to give a better idea of the comparison and the way in which the oscillations are damped, reproductions from two photographs are given in Plate VI.

The Resistance of Hydrogen.

| Pressure of gas. | Number of half oscillations. | | | Resistance in ohms. | | |
|------------------|------------------------------|--------------------|--------------------|---------------------|--------------------|--------------------|
| | Capacity = 6,000. | Capacity = 12,000. | Capacity = 18,000. | Capacity = 6,000. | Capacity = 12,000. | Capacity = 18,000. |
| millimeters | | | | ohms | ohms over 100 | ohms |
| 13.5 | | 0 | | | | |
| 10.0 | $\frac{1}{2}$ | | 2 | 50 ? | | 15 |
| 5.0 | 1 | 2 | 2 | 30 | 20 | 15 |
| 3.6 | | 2 | | | 20 | |
| 3.0 | | 3 | 3 | | 15 | 10 |
| 2.0 | 2 | 3 | 3 | 20 | 15 | 10 |
| 1.8 | | 3 | | | 15 | |
| 1.25 | 3 | 3 | 4 | 15 | 15 | 7 |
| 1.15 | | 4 | | | 10 | |
| 0.85 | | $5\frac{1}{2}$ | | | 9 | |
| 0.75 | | $6\frac{1}{2}$ | | | $5\frac{1}{2}$ | |
| 0.60 | | 7 | 6 | | 5 | 5 |
| 0.40 | | 6 | | | 6. | |
| 0.31 | $6\frac{1}{2}$ | 7 | 6 | 7 | 5. | 5 |
| 0.21 | | 6 | | | 6. | |
| 0.15 | 5 | | 6 + | 10 | | 5 |
| 0.1 | | $5\frac{1}{2}$ (?) | | | 7 ? | |
| 0.05 | $4\frac{1}{2}$ | no spark | no spark | 11 | | |

Besides these measurements of hydrogen and nitrogen, several photographs were made of sparks sent through some of Lord Rayleigh's argon contained in sealed tubes. Since the capillaries were not in every case equal in diameter, the results are not wholly comparable with one another or with those in the two tables given above. Two half oscillations each were

observed in the photographs of argon at 1, 2, and 3^{mm} pressure contained in tubes with very fine capillaries, while six half oscillations were observed in tubes about like those used for nitrogen and hydrogen. This shows that the form of the tube influences very materially the resistance. As a very small jar will provide enough electricity to give the blue spectrum of argon, the resistance of a tube containing the gas at 1^{mm} pressure was determined with a capacity of about 1,000 as well as with the usual capacities 6,000, 12,000 and 18,000 electrostatic units. Somewhat over six half oscillations were observed in each case, corresponding to resistance of about thirteen, eight, six-and-a-half, and five ohms respectively. In all, about a thousand photographs of sparks through the various gases were made.

The Resistance of Nitrogen.

| Pressure of gas in millimeters. | Number of half oscillations. | | | Resistance in ohms. | | |
|---------------------------------|------------------------------|--------------------------|--------------------------|---------------------|-------------------|-------------------|
| | Capacity = 6,000 units. | Capacity = 12,000 units. | Capacity = 18,000 units. | Capacity = 6,000 | Capacity = 12,000 | Capacity = 18,000 |
| | | | | ohms. | ohms. | ohms. |
| 9.5 | | 1 | | | 30 | |
| 5.0 | 1 (faint) | 1½ | 1½ | 35 | 25 | 23 |
| 4.2 | | 1½ | | | 25 | |
| 2.7 | 2 | | 3 | 20 | | 10 ? |
| 2. | 2 | 2 | 2(?) | 20 | 20 | 15 |
| 1.7 | | 3 | | | 15 | |
| 1.3 | | 3 | | | 15 | |
| 1.04 | 3 | 4 | 3½ | 15 | 10 | 8 |
| 0.70 | | 4 | | | 10 | |
| 0.50 | 3½ | 5 | 4 | | 8 | 7 |
| 0.30 | 4 | | 6 | 12 | | 5 |
| 0.26 | 5½ | | 5½(?) | | | 5.5 |
| 0.22 | | 8 | | | 4.5 | |
| 0.15 | 6½ | 8½ | | 7 | 4 | |
| 0.07 | 5 | 8 | | 10 | 4.5 | |
| 0.05 | | 7 | | | 5 | |
| 0.03 | | 8 | | | 4.5 | |
| 0.02 | | 5 | | | 8 | |
| 0.01 | | 5 | | | 8 | |
| 0.005 | no spark | no spark | no spark | — | — | — |

The evidence of all these experiments is unequivocal, and may be summed up under the following heads:

I. *The resistance of a gas at low pressure to the oscillatory discharge is equivalent to only a very small ohmic resistance.*

II. *This resistance is in general greater, the less the quantity of electricity.*

III. *Down to a very small pressure, this resistance decreases with the tension of the gas.* At a pressure considerably below the minima in the potential curves given on p. 328 the resistance seems to reach a minimum, but the irregularity of the sparks in this region make this last minimum somewhat uncer-

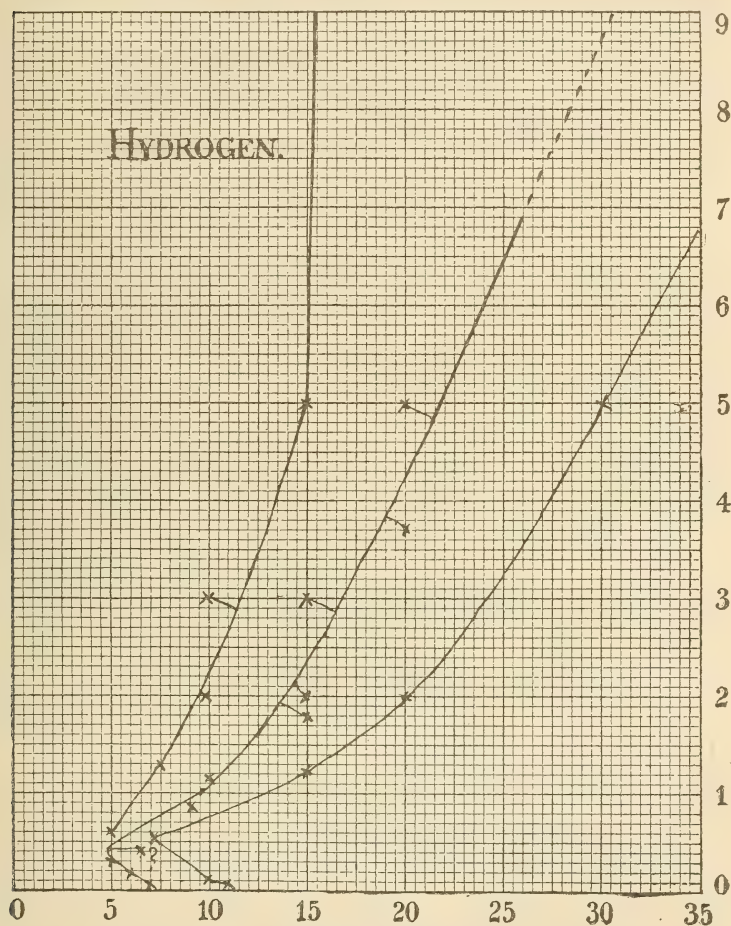


FIG. 3. Ohms are plotted horizontally.
Millimeters of pressure are plotted vertically.

tain. The minima of resistance probably vary with the quantity of electricity discharged as well as with the specific properties of the gas. The minimum for nitrogen is attained at a much lower pressure than that of hydrogen.

IV. *The form of the tube has an important effect upon the resistance of the gas.*

V. *With the oscillatory discharge it is evident that the electrodes produce far less effect than with the continuous discharge.*

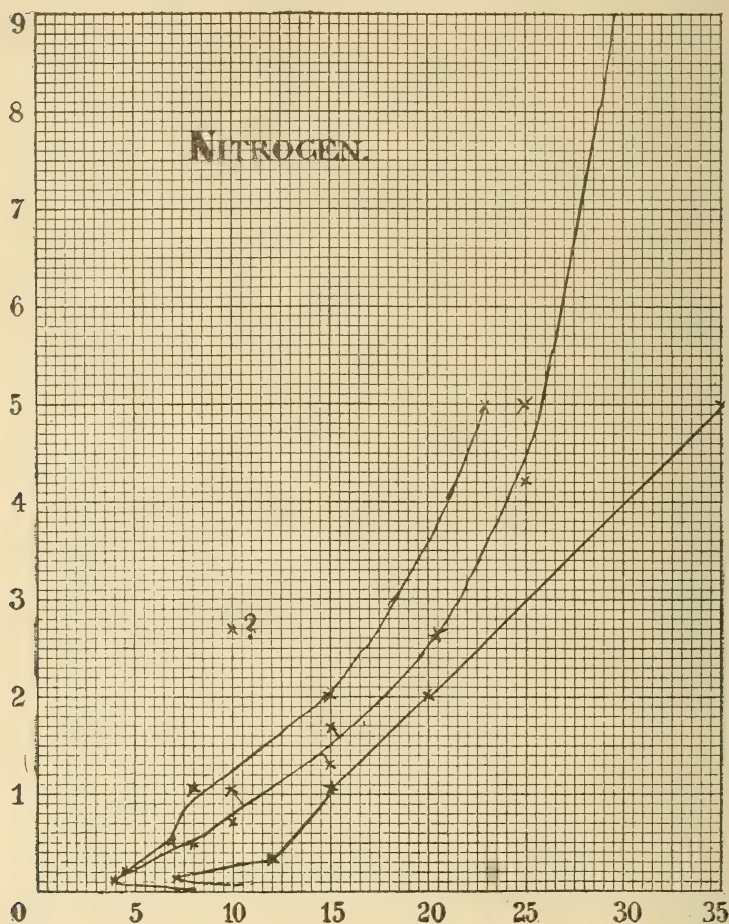


FIG. 4. Ohms are plotted horizontally.
Millimeters of pressure are plotted vertically.

These conclusions are not wholly without support in the literature of the subject. J. J. Thomson's researches with tubes without electrodes* show that a rarified gas must have

* Recent researches in electricity and magnetism, p. 92. This book contains an admirable résumé of the whole subject.

an extremely low resistance to the oscillatory discharge of electricity, and Jaumann* found that the "electric strength" of a gas increased as the quantity of electricity diminished. But all earlier accurate measurements have been made with continuous currents, whose relations are very different from those of the sudden discharge of a condenser which we have studied. The continuous current meets with great opposition, especially at the negative electrode, where much heat is developed. The oscillatory discharge meets with very little opposition, and correspondingly we find that here the greatest heat is developed in the gas itself, especially in the capillary tube, the electrodes remaining comparatively cool. This experiment we have tried repeatedly, sending exactly equal quantities of electricity through the tube in each fashion, and observing great differences in the heating effects. Moreover, even in the continuously glowing gas itself, apart from the electrodes, the potential difference, if due to resistance alone, corresponds to a vastly greater resistance than that opposed to the condenser discharge, according to Hittorf's results, already quoted.

It is clear that the quantity of electricity going through the tube in a given time is almost incredibly different in the two cases. This difference has not been enough emphasized in the literature upon the subject. Supposing that the battery and other resistance are so regulated as to supply a milliamperere of current, and the condenser is of such a size that when it is connected the spark passes ten times a second. These conditions were frequently those of our experiments. The spark, judging from our photographs, certainly does not last more than one millionth of a second, hence the current strength at the instant of the discharge must be at least 100,000 times as great as that of the continuous discharge without the condenser, or must amount to 100 amperes.

Jaumann's observation that the opposition to the current is less as the current increases, and our conclusion (III) that the resistance is less with the larger capacity, are in reality observations which may be represented as the two extremities of a long curve. This curve is formed by the relation of milliamperes to megohms on one end, and of hundreds of amperes to ohms upon the other. The part of the curve between these two extremities is very hard to investigate with our present means, and indeed it seems to behave differently with different gases. For these two conditions are represented in any given case by the two spectra of the gases, and as we increase the current we observe varying relations between these spectra. In the case of hydrogen the spectrum of four

* Sitz. Berichte, Wien Akad., vol. xevii, p. 765.

visible lines gradually increases in brilliancy with the gradual fading of the many-lined spectrum of the lower temperatures as the current is increased; and only when the current strength becomes very great do the extra lines disappear. In other words, the change from one condition to the other is gradual. In the case of nitrogen, on the other hand, the change is abrupt; and often when the gas is near its sensitive point some sparks will go through with little opposition, while others give the banded spectrum and the non-oscillatory photograph, showing that the resistance was large. Argon is like nitrogen in the suddenness of the transition, but its transition takes place with much weaker currents than with either hydrogen or nitrogen. We have repeatedly found argon to give the pure blue spectrum under the influence of the discharge of the full battery with very little resistance in the circuit without any condenser, or with less than eight amperes; for the resistance of each cell of the battery is about the quarter of an ohm.

One of the great difficulties of investigating the intermediate part of the curve lies in the fact that no tube is strong enough to stand the continuous application of temperatures as high as those developed by the corresponding current. On the other hand, the repeated instantaneous discharge, which the tube will stand, cannot be estimated when the resistance rises above the very small amount necessary to damp out the oscillations.

The question whether the change in the spectrum upon increasing the current, is due to greater heat or to the oscillatory motion, is one which is not easily settled, because the last trace of the return oscillation requires hundreds of ohms for its damping; and under these conditions this oscillation is not easily photographed. The fact that argon offers no less resistance than hydrogen or nitrogen to electric oscillations, but nevertheless is much more sensitive to increased current, tends to show that the important factor in the question is not the oscillatory nature of the discharge, but only the great quantity which is always attendant upon oscillatory discharges.

Since gases do not strictly follow Ohms law, we cannot assume that the formula $R = \sqrt{\frac{4L}{c}}$ in which R is resistance,

L =self induction, and c =capacity, and which gives the limiting value of R for non-oscillatory discharges, rigidly holds. If, however, we obtain a white glow in hydrogen gas due to the unidirectional discharge of a large condenser through a large outside resistance and then proceed to increase the electromotive force, and consequently the strength of the current in our unidirectional discharge, we can determine whether this form of discharge is competent to produce the red glow in hydrogen. The apparatus which was used for this purpose

consisted of a step-up transformer consisting of two secondaries of many turns of fine wire which were slipped upon a long primary. When the secondaries were coupled in series the electromotive force of the discharge was doubled, without any considerable change in the capacity. As a matter of fact, the glow was seen to be perceptibly redder with two coils than with one, showing that the change in the quantity is the essential feature in the change of the spectrum.

While this conclusion interferes with the strict application of the word talantoscope to an argon-tube, the use of the tube as a talantoscope, nevertheless, remains; for while the oscillations and the blue spectrum are not strictly dependent upon one another, they are both dependent upon the same final cause.

The conclusion that the large quantity of electricity, and therefore, the high temperature caused by the discharge, is the cause of the very much diminished resistance of the tube and the corresponding spectrum, leads us at once to consider the energetics of the problem. On the assumption that the departure from Ohms law is not large,* since $C = \frac{E}{R}$ and the

amount of the impedance in the circuit is so small as to be neglected, we shall have an amount of energy developed in the tube for perhaps the millionth part of a second equal to CE. With an electromotive force of 10,000 volts and a resistance of ten ohms, a current of 1,000 amperes must be obtained, and this multiplied by 10,000 and divided by 746 gives the electrical horse power if the current were maintained for a second. The corresponding value is over ten thousand, and this corresponds to an excessively high temperature for a very brief space of time.

Of course a bolometer or any other thermometer in the tube could not indicate this energy, for it is of very short duration and even in its brief existence undoubtedly does not affect the whole mass of the gas through which the discharge passes. J. J. Thomson has called attention to this fact.† In the case of the continuous discharge the temperature is undoubtedly vastly lower, but even here it is probable that the pale brush does not concern all the particles of the rarified gas.

* Moreover we find that the electrostatic capacity of the Geissler tube is not sufficient to affect the period of the oscillatory movement. To decide this we arranged a rocking key which interposed first the Geissler tube and then immediately afterward a wire of self-induction equal to that of the tube, and photographed the oscillatory discharge through the two circuits. No change could be perceived in the period of the two discharges. If the electrostatic capacity of a Geissler tube were large an argon tube would not be as sensitive as it is to slight changes in electrostatic capacity in the circuit.

† Recent researches, p. 167.

Therefore calculations or experimental determinations of the average temperature of a large tube, such as those of Warburg* and Wood, while interesting as relative considerations, give no clue as to the kinetic energy of the molecules which actually carry the current. For such a clue one must refer to experiments of the sort we describe.

All the results recorded in this paper support the well known hypothesis that the current when disruptive is carried by dissociated molecules. The continuous discharge is best explained by conceiving of a polarized condition, in which the molecules are in some way bound together by the electric energy which is striving to force itself through them. As the current increases, the amount of the heat increases, until it reaches a stage when some of the gas is freed from this bondage—when the molecules not only separate from their electric embrace, but split into their component atoms. Then, if a large quantity of electricity is at hand to discharge itself, the rate of discharge increases with enormous rapidity, resulting in more dissociation, and the resistance is almost entirely broken down. A good résumé of the present state of this hypothesis is given in *Nature*, Jan. 28, 1897, p. 310, and to this statement our determination of the resistance makes an important addition.

Hydrogen and oxygen cannot be dissociated to any appreciable extent at ordinary temperatures and pressures, otherwise water would form when they were mixed. We have no vapor densities of hydrogen or oxygen at temperatures which show dissociation, but this is no reason for believing that at temperatures of three thousand degrees or more dissociation does not take place. Indeed, the burning of hydrogen and oxygen gives us every reason for believing that the tendency of both hydrogen and oxygen molecules to dissociate increases with the temperature. Chlorine, bromine, and iodine are all known to dissociate at high temperatures, and to conduct electricity well under those conditions.

Another point in favor of ascribing the red glow of hydrogen to dissociation is to be found in the fact that rarified aqueous vapor gives the pure "four-line" spectrum much more easily than hydrogen itself. In order to give any hydrogen spectrum at all, the vapor must be dissociated. Of course the dissociation takes place only at the moment of the discharge, the atoms combining again when cold. It is caused by the heat of the discharge, and not by electrolysis, although that too may take place at the electrodes. In short, there is every reason to believe that at temperatures as high as those with which we are dealing, the hydrogen is split apart into hydro-

* *Wied. Ann.*, liv, 265.

gen atoms, and that these atoms, or perhaps the energy involved in the act of splitting them, are responsible for the "four line" red spectrum. The fact cannot be too strongly emphasized that this sort of dissociation is very different indeed from the electrolytic dissociation of solutions.

In order to find if the structure which is dissociated by the spark is the molecule or some more complex structure, mercury vapor was subjected first to the continuous discharge and then to the oscillatory. Since the spectra obtained were widely different, the conclusion, at least in the case of the mercury, is that the structure is complex; for mercury molecules are monatomic. This conclusion is reinforced by many other facts known about the continuous discharge. Hence the existence of two argon spectra does not give any reason for disbelieving the evidence of specific heat with regard to the monatomic nature of argon.

From the point of view of a mechanical conception of the causes producing the two spectra of a gas, it is easy to imagine that when the atoms are bound together in the polarized condition, the electricity by a succession of readjustments may travel step by step from one end of the tube to the other, at a comparatively low temperature, and so cause quite a different set of electro-magnetic vibrations from those depending upon the breaking down of this polarized system. The evidence that the second spectrum given by the oscillatory discharge is due either to the act of separating the atoms from one another, or to the passage of the electricity through the atoms already set free by the heat, has been given above. Hittorf's experiments, in which he was able to send a very strong continuous current through a gas without the production of light, would seem to indicate that the light is due to energy involved at the moment of dissociation, but the spectra of the solar prominences lead to the opposite inference, and conclusive evidence upon this point is wanting. The dissimilar behavior of different gases is easily accounted for by considering the two causes which are supposed to resist the dissociation: in the first place, the "polarized" condition of the molecules, and in the next place the chemical affinity of the atoms for one another. This last force is usually admitted to be greater in the case of nitrogen than in that of hydrogen, hence the difficulty, the irregularity and the abruptness of the transition in the former case. One should expect that a monatomic gas, like argon, where the polarization alone prevents the passage of the current, would be easier to change in this respect, as indeed it is. The fact that the second spectrum of mercury is not very easily obtained, militates against this explanation, however.

Assuming, then, that the red spectrum of hydrogen is due to the sudden occurrence of the reaction



it is very interesting to note that our results agree with the necessary deductions from the law of mass action as applied to this case. If the reaction is supposed to take place isothermally at a very high temperature, it is manifest that the progress of the reaction from right to left must increase as the concentration of the hydrogen—in other words, the tension of gas—is diminished. This we find to be the case: the resistance of the gas increases and the purity of the “four-line” spectrum diminishes as the tension of the gas increases, except when the gas is exceedingly rarified. In this last case it is probable that the number of atoms present, even if all were free, would be insufficient to carry all the current. Hence we should expect to find this minimum at a lower pressure when the capacity of the condenser employed was less; but unfortunately the spark is too uncertain at these very low temperatures, even with twenty thousand volts from the complete battery, to give definite results.

Since hydrogen undoubtedly requires a very large amount of heat for its dissociation, it follows that when the temperature is raised while the pressure is kept constant, more atoms should be set free. We find, as a matter of fact, that the resistance diminishes as we increase the capacity of the condenser—that is to say, the heat of the discharge. The case is exactly analogous to the dissociation of nitric peroxide observed by E. and L. Natanson.*

Our work leads one to infer that since a very high temperature is needed to produce the “four-line” spectrum of hydrogen, this high temperature must be present wherever this spectrum appears; for example, in the solar prominences and in many fixed stars. The higher the tension of the gas, the higher the temperature required; hence one must know the atmospheric pressures in these heavenly bodies before attempting to guess at the actual temperature attained; but there can be no doubt that this temperature is in any case far beyond the reach of any earthly means except the electric discharge which we have been considering.

* Wied. Ann., xxiv, 454, and xxvii, 606.

ART. XXXII.—*Does a Vacuum conduct Electricity?*; by
JOHN TROWBRIDGE.

THIS question has been answered affirmatively by Edlund, and negatively by the latest researches of Professor J. J. Thomson. Some recent experiments of my own lead me to believe that the principal resistance resides at the boundary between the highly rarified space in a Crookes tube, for instance, and the electrodes. I find by photography that the electrical discharge which produces the Röntgen rays oscillates and the number of oscillations gave in the tube experimented with a resistance in the tube at the moment of discharge of only five ohms. In the case of a disruptive discharge of electricity, therefore, after the initial resistance of the medium breaks down it exhibits hardly any resistance during the oscillations of the discharge. I produced the proper conditions by employing a Planté rheostatic machine* or in other words an arrangement by means of which Leyden jars can be charged in multiple and discharged in series. A highly disruptive spark can thus be obtained with a storage battery of ten thousand cells. This Planté accumulator does not reverse its poles and is therefore extremely useful in studying the Röntgen phenomenon. I was extremely interested, however, in discovering that the electrical discharge through the Crookes tube at the moment when the Röntgen rays were being produced most strongly was an oscillatory one, of a high period, about ten million oscillations per second in the case I examined. Perfect definition, therefore, cannot be obtained even with the use of an electrical machine unless care is taken to shield the anode from the photographic plate.

By applying the same method to electrical sparks in air, I have discovered that a spark of six inches indicates little if any more resistance than a spark of one inch. The sparks therefore do not follow Ohm's law. All my experiments lead me to believe that a disruptive discharge of electricity encounters its chief resistance at the going over layer between the electrodes and the medium; and that during the discharge in a highly rarified medium very little resistance is encountered. By the method employed an increase or diminution of resistance of half an ohm can be detected. The resistance of the Crookes tube to the disruptive discharges seems to diminish with the increase of rarefaction or the nearer we approach a vacuum.

* Comptes Rendus, lxxxv, p. 794, 1877.

ART. XXXIII.—*A Note on the "Plasticity" of Glacial Ice ;*
by ISRAEL C. RUSSELL.

It is conceded, I think, by all students of glacial phenomena, that the flow of glaciers is at least analogous to the flow of plastic solids under the influence of gravity. That the flow of glaciers is due to true plasticity, however, as claimed by Forbes and others, cannot be admitted in view of somewhat recent experiments on the bending of ice by McConnell, Kidd and Mügge.*

These experiments have demonstrated that a bar of ice cut from a single crystal, with the optic axis perpendicular to two of the side faces, when subjected to a bending stress, will bend freely in the plane of the optic axis, but not at all in a plane perpendicular to that axis. In the bent crystals the optic axis in any part is normal to the bent face in that part. As stated by McConnell, a crystal when thus tested behaves as if it were composed of an infinite number of thin sheets of paper, normal to its optic axis, and attached to each other by some viscous substance which allowed one to slide over the next with great difficulty. The greatest freedom of movement was found to occur when the ice experimented on was near the melting point, and became less and less with a decrease of temperature. In certain of the experiments referred to, the freedom of movement at -2° C. was twice as great as at -10° C.

These experiments seem to furnish an explanation of some of the phases of glacial motion, and of the growth of the granules of glacial ice. When thin sections of glacial ice are examined by means of polarized light,† it is seen that the granules of which it is composed are fragments of ice crystals, or perhaps imperfectly formed crystals, which interlock one with another so that the structure resembles that of coarsely crystalline dolomite.

The optic axes of the granules are without orderly arrangement, but have all directions. Pressure brought to bear on such granular ice in a definite direction, would cause movement in the crystal fragments or granules, whose optic axes were in the plane of pressure, but would not change the forms of the crystal fragments not thus oriented. The crystal frag-

* J. C. McConnell and D. A. Kidd: "On the plasticity of glacial and other ice," Roy. Soc. London. Proc., vol. xlv, 1883, pp 131-161. J. C. McConnell: "On the plasticity of an ice crystal," *ibid.* vol. xlviii, 1890, pp. 256-260; vol. xlix, 1891, pp. 323-343. O. Mügge: "Ueber die Plasticität der Eiskrystalle," Separat-Abdruck aus dem Neuen Jahrbuch für Mineralogie, etc., 1895, Bd. II, cited in the Journal of Geology, vol. iii, 1895, pp 965, 966.

† R. M. Deeley and George Fletcher: "The structure of glacial ice and its bearing upon glacial motion," Geol. Mag. (London), Decade 4, vol. ii, 1895, pp. 152-162.

ments having their optic axes in the plane of pressure would be changed in shape, as in the experiments cited above, by movements along gliding planes.

The stresses in glaciers are manifestly in various directions, and owing to the flow of the ice, inequalities of the rock surfaces beneath, etc., must be exceedingly complex. As the crystal fragments of which glaciers are composed are without orderly arrangement, it is evident that some of them will be properly oriented to be deformed by a differential movement of their parts along gliding planes, by pressure acting in any direction. Under diverse stresses the resultant motion would be in the direction of least resistance. That is, the granular ice would behave like a plastic solid.

Owing to diversity in orientation, it follows that adjacent granules might be deformed in different directions; and that diverse movements of adjacent granules might result.

The yielding of glacial ice to pressure, we conceive, is due to movements along gliding planes in the granules of which it is composed. If this process is continued, the granules will evidently be destroyed by being divided along the planes on which movement occurs, but the resulting subdivisions—or "plates" perhaps we may term them,—are re-united probably by the process of regelation. The plates which after uniting have the same orientation, would form new granules. The longer this process is continued, or in other words, the farther a glacier flows, the greater the chances that a large number of plates will come together with similar orientation and the larger will be the resulting granules.

Under the hypothesis here suggested, the granules of glacial ice are considered as an inheritance from the granules in the ice formed by partial melting and re-freezing of *névé* snow. The granules at first are minute, but under the pressure of ice at higher levels they yield along gliding planes, and a resultant motion similar to that of plastic solids under like conditions is initiated. The granules are destroyed by this process, but progressive motion leads to the union of a constantly increasing number of the plates into which they are divided, and the growth of larger granules.

As movement in ice crystals, along gliding planes, takes place with increased freedom the nearer the temperature approaches the melting point, we should expect, under the hypothesis here suggested, that glacial motion would fluctuate with changes of temperature. This, as is well known, is what has been observed.

It is evident that one granule in a mass of glacial ice cannot be deformed by movements of its various portions along gliding planes, unless room for the change of form is available. As the lower extremity of a glacier is normally exposed to a

higher temperature than its upper portions, and as the freedom of motion in ice crystals is greatest the nearer the temperature of the ice approaches the melting point, we should expect, other conditions being the same, that the rate of change in the granules composing a glacier would be greatest at its lower extremity and decrease progressively toward its névé. Conditions which would permit granules to change their shape would thus be transmitted from the lower extremity of a glacier toward its source. The deformation of granules may also be facilitated by the formation of crevasses. In fact, under the hypothesis here considered, crevasses seem to be an important element in glacial flow.

Granules so situated with reference to the direction of pressure that they cannot yield along gliding planes, may be moved bodily, owing to the movements of adjacent granules, or they may be fractured and the fragments united to neighboring granules, or themselves acquire additions and form new granules. This explanation seems in harmony with what has been observed in reference to the gradual increase in the size of the granules of glacial ice with the distance it flows; and also with the fact that this gradual increase in size is accompanied by the pressure at all times of small granules.

An objection that may perhaps be advanced to the views here expressed in reference to the growth of granules, is that, owing to the flow of glaciers, the granules composing them would become similarly oriented, that is, the optic axes of the crystal fragments would all become parallel to the direction of flow. The varying stresses, due to inequalities of channel, the disturbing conditions introduced by englacial débris, inequalities in temperature, etc., would apparently lead to the growth of granules with their optic axes variously oriented.

It has been asked: "Why, if glacial ice responds to pressure like a plastic solid, do not boulders on the surface of a glacier depress the ice beneath?" I would suggest in reply that a boulder shields the ice beneath from the heat of the sun and thus diminishes the conditions favorable to movement along the gliding planes in the granules composing it. The ice in the shadow of a boulder is stiffened possibly to a considerable depth, and forms a platform on which the protecting rock-mass is carried. The larger the boulder, the broader and deeper the area of rigid ice in its shadow.

If the explanation just suggested is correct, measurements of glacial flow where narrow medial moraines occur, should show a less rapid movement than the adjacent lanes of clear ice. This and other tests—especially a study of the ice granules at many points in a glacier,—need to be made before the explanation of the plasticity of glacial ice proposed in this note can be considered as more than a working hypothesis.

ART. XXXIV. — *The Affinities of Hesperornis*; by
O. C. MARSH.

IN the autumn of 1870, I discovered in the Cretaceous of western Kansas the remains of a very large swimming bird, which in many respects is the most interesting member of the class hitherto found, living or extinct. During the following year, other specimens were obtained in the same region, and one of them, a nearly perfect skeleton, I named *Hesperornis regalis*.* In subsequent careful researches, extending over several years, I secured various other specimens in fine preservation, from the same horizon and the same general region, and thus was enabled to make a systematic investigation of the structure and affinities of the remarkable group of birds of which *Hesperornis* is the type. The results of this and other researches were brought together in 1880, in an illustrated monograph.†

In the concluding chapter on *Hesperornis*, I discussed the affinities of this genus, based upon a careful study of all the known remains. Especial attention was devoted to the skull and scapular arch, which showed Struthious features, and these were duly weighed against the more apparent characters of the hind limbs, that strongly resembled those of modern diving birds, thus suggesting a near relationship to this group, of which *Colymbus* is a type. In summing up the case, I decided in favor of the Ostrich features, and recorded this opinion as follows:

"The Struthious characters, seen in *Hesperornis*, should probably be regarded as evidence of real affinity, and in this case *Hesperornis* would be essentially a carnivorous, swimming Ostrich." (Odontornithes, p. 114.)

This conclusion, a result of nearly ten years' exploration and study, based upon a large number of very perfect specimens and a comparison with many recent and extinct birds, did not meet with general acceptance. Various authors who had not seen the original specimens, or made a special study of any allied forms, seem to have accepted without hesitation the striking adaptive characters of the posterior limbs as the key to real affinities, and likewise put this opinion on record. The compilers of such knowledge followed suit, and before long the Ratite affinities of *Hesperornis* were seldom alluded to in scientific literature.

* This Journal, vol. iii, p. 56, January; and p. 360, May, 1872.

† Odontornithes: a Monograph on the Extinct Toothed Birds of North America. 4to, 34 plates, Washington, 1880.

Several times, I was much tempted to set the matter right as far as possible by reminding the critics that they had overlooked important points in the argument, and that new evidence brought to light, although not conclusive, tended to support my original conclusion that *Hesperornis* was essentially a swimming Ostrich, while its resemblance to modern diving birds was based upon adaptive characters. On reflection, however, I concluded that such a statement would doubtless lead to useless discussion, especially on the part of those who had no new facts to offer, and, having myself more important work on hand, I remained silent, leaving to future discoveries the final decision of the question at issue.

It is an interesting fact that this decision is now on record. A quarter of a century after the discovery of *Hesperornis*, and a decade and a half after its biography was written in the *Odontornithes*, its true affinities, as recorded in that volume, are now confirmed beyond dispute. In the same region where the type specimen was discovered, a remarkably perfect *Hesperornis*, with feathers in place, has been found, and these feathers are the typical plumage of an Ostrich.*

Yale University, New Haven, Conn., March 16th, 1897.

* Williston, *Kansas University Quarterly*, vol. v, p. 53, July, 1896.

SCIENTIFIC INTELLIGENCE.

I. GEOLOGY AND MINERALOGY.

1. *Vertebrate Fossils of the Denver Basin*; by O. C. MARSH. Extract from Monographs of the United States Geological Survey, vol. xxvii, pp. 473-550, 80 figures in text, and plates xxi-xxxi.—Denver is in the midst of a number of geological horizons which are capable of exact determination from the vertebrate fossils they contain. These beds have been made the subject of special study by the author of this paper, and the separate horizons have each received distinctive names based upon the presence of a characteristic vertebrate genus. The Mesozoic and Cenozoic include essentially all the strata of the Denver Basin, and the oldest rocks positively identified belong to the Jurassic, of which the Hallopus, Baptonodon, and Atlantosaurus beds are recognized. The chief vertebrate horizons of the Cretaceous in this region include the marine Pteranodon and the fresh-water Ceratops beds. The Eocene is absent on the eastern slopes of the Rocky Mountains here and to the north, but is known farther south. The Miocene and Pliocene are present, the former containing the Brontotherium, and the latter, the Pliohippus beds. After the geological discussions, there follows a description of the leading mammalian, avian, and reptilian forms of each horizon, accompanied by figures in the text and restorations of the complete animals on the plates.

The object of the chapter, as stated by the author, is to indicate, first, the relative position of the various horizons containing vertebrate faunas; second, to give accurate figures of the important type specimens, so that the strata containing their remains may be thus identified; and, in conclusion, to state briefly something of the life-history of these extinct animals, and under what conditions they lived and died.

C. E. B.

2. *Geology of Minnesota, Vol. III, Part 2, of the Final Report. Paleontology*; by E. O. ULRICH, JOHN M. CLARK, WILBUR H. SCOFIELD, N. H. WINCHELL. pp. lxxxiii-cliv, 475-1087, 1897.—An introductory chapter gives a correlation of the Lower Silurian deposits of the upper Mississippi province, revising to some extent the previously published correlation on the basis of the total evidence of stratigraphy and paleontology. The Trenton period is represented by the *St. Peters sandstone* of the Chazy group; the *Buff limestone*, *Vanuxemia* and *Stictoporella* beds of the Stones River group; the *Rhinidictya*, *Ctenodonta*, *Phylloporina* and *Facoid* or *Orthis Spectinella* beds of the Black River group; the *Clitambonites*, *Fusispira*, and *Maclurea* beds of the Trenton group (galena, limestone and shale, Nashville group). The Hudson River or Cincinnati period (the authors prefer the latter name, but have adopted the former) is represented in the Minnesota area by rocks referred to the Utica group, and to the Richmond group. The total number of species recognized in the

Trenton period strata is 696, and 113 species from the rocks of the Hudson River period.

The body of the volume consists of exhaustive descriptions and illustrations of the fossil species of the Lower Silurian (Ordovician) formations of Minnesota. The chapter on the Lamellibranchiata is by E. O. Ulrich; the author has succeeded in figuring a good number of interiors and hinge teeth of these ancient types. The Ostracoda are also described by Ulrich. The chapter on Trilobites and Cephalopoda are by J. M. Clark.

Mr. Ulrich and the late Mr. W. H. Schofield (who died during the preparation of the work) prepared the chapter on the Gastropoda. The large number of forms related to Bellerophon and Bucania, and to Pleurotomaria and associates are worthy of particular notice. The authors propose the erection of a new suborder, *Bellerophon-tacea*, to include twenty-three genera divided into the following five families; viz., Cyrtolitidæ, Protowarthiidae, Bucaniidæ, Bellerophontiidae and Carinaropsidæ. A number of new genera are described. Under the Pectinibranchiata the new suborder *Eotomacea* is proposed to include the families Rhaphistomidæ, Pleurotomariidæ, Euomphalidæ, Trochidæ, and some others. In this suborder a large number of new species and several new genera are described from the Minnesota material. The illustrations are numerous and well done; and the work is a rich contribution to knowledge of the Ordovician forms of North America. H. S. W.

3. *Geological survey of Alabama; Report on the valley regions of Alabama (Paleozoic strata)* by HENRY McCALLEY, Assistant State Geologist. Part I. The Tennessee valley region. pp. 1-436, with illustrations, 1896.—The report contains a valuable amount of information regarding the local details of stratigraphy and the geological products of economic importance.

4. *Catalogue and index of contributions to North American Geology, 1732-1891*; by N. H. DARTON. Bull. No. 127, U. S. Geol. Surv., pp. 1-1045. 1896.—This index is a work which will be of the greatest time-saving value to all students of North American geology. The literature is recorded alphabetically under both author and subject primary titles, and under each primary title the entries are arranged secondarily in chronological order.

Papers and books purely paleontologic or purely mineralogic are not included. It would not be surprising if omissions occur even in a work so carefully done as this one, and the author requests readers to send additional references or information for a supplement to him, care of the United States Geological Survey, Washington, D. C. H. S. W.

5. *Description géologique de la partie sud-est de la 14-me feuille de la VII zone de la carte générale du gouvernement Tomsk (Feuille Balachouka)*; par P. VENUKOFF (in Russian with French résumé), pp. 1-151. 1896.—The formations described in this paper include limestone formations containing an abundant characteristic Neodevonian fauna, above which are Carboniferous

limestones containing abundant characteristic Carboniferous faunas; lists of both of the faunas are given. H. S. W.

6. *Catalogus Mammalium tam viventium quam fossilium*, a Dr. E. L. TROUESSART. Nov. ed. (*prima completa*). Fascic. 1. *Primates, Prosimiae, Chiroptera, Insectivora*, pp. 1-218 (Berlin: R. H. Friedländer & Sohn), 1897.—This new edition of Trouessart's list professes to be complete, and offers in a compact form a reference catalogue of all the known species, fossil and living, of mammals of the first four orders, with bibliography and geographical distribution of each species.

7. *Congrès géologique international*.—A second circular has been issued by the committee announcing the dates of the meeting and of the several excursions. The session of the Congress will be held at St. Petersburg, beginning Aug. 29th and closing Sept. 4th. The excursions before the meeting are three: A, to the Ural mountains, departing from Moscow July 30th and returning to St. Petersburg Aug. 26th; B, in Esthonia Aug. 13th to Aug. 27th; C, excursion in Finland, Aug. 21st to Aug. 28th, starting at Helsingfors. After the meeting the grand excursion to the Caucasus will depart from St. Petersburg Sept. 5th, by three different routes, the three parties coming together again at Wladikavkaz about Sept. 15th, and the excursion ends at Sébastopol, Oct. 4th.

Each member attending the Congress will receive a free pass entitling him to transit in first class cars over the Russian and Finnish railroads. The other expenses connected with the several excursions are estimated at 400 francs for the Ural, 135 fr. for the Esthonia, and 50 fr. for the Finland excursions. The expense for the grand Caucasus excursion will be 665 francs for the main part and additional amounts (40 to 270 fr.) for the several branch excursions arranged in connection with it. The address of the local secretary is A. O. Michalski, Comité Géologique, St. Petersburg, Wassili Ostrow, 4^{me} Ligne, Russia. H. S. W.

8. *Geology of Santa Catalina Island*; by WM. S. TANGIER SMITH (Proc. Cal. Acad. Sci., Third Ser., Geol., vol. i, No. I. 1897. 8vo, 71 pp., 3 pl.)—The excellent and enthusiastic work in detailed geology, petrography and mineralogy which is being carried on in the California Coast region by an earnest group of young workers under the guidance of Prof. A. C. Lawson, is well known. The present paper adds another chapter to the work already done and we trust another worker in this great field of hidden wealth.

The author describes the general features of the island and especially the eruptive rocks which make up the greater part of its area; of these careful petrographic descriptions and analyses are given. The series comprises diorites, porphyrites, andesites and rhyolite; areas of tuffs, schists and quartzite are also studied, and the work concludes with an outline of the geologic history of the island. An excellent colored map is added. L. V. P.

9. *Elementary Geology*; by RALPH S. TARR. pp. 499. New

York 1897 (The Macmillan Co.; price \$1.40).—The author has here attempted to present the subject of geology in a form suitable for the comprehension of quite elementary students; he dwells especially upon the dynamical side of the subject, rightly regarding the full treatment of historical and stratigraphical geology as belonging to an advanced course of study. In many respects he has done his work well, but it is to be regretted that he has allowed himself to be careless in writing at a number of points, and, moreover, that occasional errors in the names of fossils and other blemishes come in, which are unfortunate in the case of a book which is to go into the hands of young students.

It is hardly allowable, for example, even in popular language, to speak of coral mud as "clay." Further, the proper use of such terms as period, age, epoch, etc., in geological chronology, is a matter to which geologists have given much thought, and it is unfortunate that they should be used by the author with so little discrimination, different terms being used for the same divisions even in the course of a single sentence. Other points might be mentioned; for example, on page 410, No. 1 of fig. 235 is called a "brachiopod" but is named "*Aulopora arachnoidia*"; the latter perhaps referring to the label, and the former to the specimen with which it was found.

The author has evidently made an effort to secure original illustrations on a liberal scale, and many of the reproductions from photographs can be highly commended, but not a few of the figures, especially in the early part of the book, bear (as printed) little or no resemblance to the objects which they are designed to illustrate. The fossils, too, which are figured in the latter part of the book are poorly selected and give but little indication of the distinguishing characters which they are intended to represent.

10. *A Catalogue of the Minerals of Tasmania*; by W. F. PETTERD. 103 pp. Launceston, 1896.—This catalogue is an extension of an earlier one published in 1893. It enumerates some 269 species which have thus far been identified among the mineral products of Tasmania. Among these are a number of considerable rarity, as crocoite, vauquelinite, eudialyte, etc., which it is interesting to learn of as occurring in a new locality. We note the following names which are now introduced into the science. DUNDASITE, from a qualitative analysis, is inferred to be a hydrated carbonate and phosphate of lead and aluminum. It forms small spherical aggregates with radiated structure, and is milky white in color, except on the surface, which is yellow-brown. It was obtained from the Adelaide mine, Dundas. HEAZLEWOODITE is a sulphide of nickel and iron, related to pentlandite but apparently not to be identified with it. According to some assays, it contains 38% of nickel. WELDITE is a silicate of aluminum and sodium from the Weld River. It occurs in white masses; hardness = 5.5; specific gravity = 2.98. It was announced by F. M. Krausé in 1884.

11. *The Production of Precious Stones in 1895*; by GEORGE

F. KUNZ.—This interesting chapter from Part iii of the Seventeenth Annual Report of the Geological Survey (Mineral Resources of the United States) has been issued in separate form.

II. BOTANY AND ZOOLOGY.

1. *A Manual and Dictionary of the Flowering Plants and Ferns*; by J. C. WILLIS, M.A., Director of the Royal Botanic Gardens, Ceylon. In two volumes, 8vo. pp. 653.—In these two handy volumes have been brought together, in an orderly and convenient form, the principal facts and cardinal principles in regard to the more important ferns and flowering plants. It is seldom that such discrimination in selection, such skill in arrangement and such perspicuity in statement, are conjoined: each one of these factors is so pronounced in the work in hand that it would, even if taken alone, make the treatise valuable; taken together, they place it in advance of any work in the same field.

Part second was written first. It comprises descriptions of the largest genera and of those of greatest importance in their relations to men, together with excellent accounts of the chief orders arranged alphabetically. Besides all this, small genera are referred to and assigned to their proper orders. Morphology, especially that which deals with adaptive mechanisms, Classification, Distribution and Economics, are presented in sufficient detail, and in an interesting way. But the author was not content with this, and therefore he prepared a supplementary volume, numbered one, which constitutes a remarkable introduction to the alphabetical portion. In this introductory part, he places the reader in possession of the essential terminology of modern botany, and carries him along through the difficulties presented by variation, and evolution in general, until he brings him face to face with modern classification. Thence he conducts the reader intelligently through the most telling part of geographical botany, and explains the relations of adaptation to the whole.

We are not inclined to find fault even with the rather too technical aspect of a few of the pages, for we have seen the experiment tried of giving the work as a whole to a reader not particularly interested in botany, who wished to glance at the author's statement of natural selection. The reader did not leave his examination of the volume until he had made himself familiar with the whole, and this, it must be confessed, is a good test. The treatise is a distinct and valuable addition to our works of reference.

G. L. G.

2. *Studien ueber den Hexenbesenrost der Berberitze*; by DR. JAKOB ERIKSSON.—In this paper, published in the *Beiträge zur Biologie der Pflanzen*, vol. viii, are given some curious facts in regard to the development of *Aecidium Magellanicum*, which was first described on *Berberis ilicifolia* in South America, but has since been observed on species of *Berberis* in Europe and differs from the ordinary *Aecidium Berberidis*, which is a stage of

Puccinia graminis. It had been suspected that *Aec. Magellanicum* was a species which was perennial on barberries, although by some mycologists it was supposed to be associated with a *Puccinia* which grows on *Avena elatior*. By his cultures made at the experiment station near Stockholm, Prof. Eriksson has shown by inoculations that, although *Aec. Magellanicum* is really a stage of the rust of *Avena elatior* to which he gives the name of *Puccinia Arrenatheri*, it is also true that two stages, the aecidium and the teleutospores, including the uredo, may be propagated perennially independently of one another on *Berberis* and *Avena* respectively. In other words the two stages of development are facultative rather than essential. When, however, the aecidium-stage is propagated perennially the normal period of incubation is much lengthened, a period of from three to four years being required.

W. G. F.

3. *Phycotheca Borealis-Americana*, Cent. vi; by Messrs. COLLINS, HOLDEN and SETCHELL—The last fascicle of this important series contains a smaller proportion than usual of fresh-water species, the marine species preponderating. Among the rarities we may mention *Phycocelis maculans*, *Entoderma Wittrockii* and *Kallymenia perforata*.

W. G. F.

4. *Analytic Keys to the Genera and Species of North American Mosses*; by CHARLES REID BARNES and FRED DEFOREST HEALD. Bulletin University Wisconsin, Science Series I i-x, 157-368, Madison, Dec., 1896.—This is an extension and revision of the *Artificial Keys to the Genera and Species of Mosses recognized in Lesquereux and James' Manual of the Mosses of North America* issued by Prof. Barnes in May, 1890, a work which proved to be of great practical service to students of our mosses. The revised edition includes an Appendix of 116 pages, which gives the descriptions of species and varieties published since the issue of Lesquereux and James's Manual in 1884 and before January 1896. The large number of species given in the Appendix, 603 in all, shows the great activity of bryologists in recent years, and the incorporation of them in the *Analytic Keys* will greatly facilitate the study of our moss-flora, for only a small number of specialists have access to the original descriptions.

W. G. F.

5. *Index Desmidiacearum citationibus locupletissimus atque Bibliographia*; by C. F. O. NORDSTEDT. Berlin. pp. 310, 4to.—This Index well deserves the name "locupletissimus," for it contains not far from 1200 titles in the Bibliographia. It may practically be called a complete index; at least, it would be difficult to imagine one more complete. The species are arranged alphabetically by specific names and under each specific name the generic names, when there are more than one, are arranged alphabetically with the reference to the literature arranged chronologically. By means of letters it is indicated whether any reference cited gives a description, figure, measurement, etc. The amount of labor required to prepare the Index must have been enormous and

the typography is excellent. The great value of this work, indispensable to algologists, lies in the fact that it is not a catalogue prepared by a professional catalogue-maker, but an Index arranged by an expert in the subject who has a thorough practical acquaintance with the Desmids themselves. W. G. F.

6. *Die Protrophie*; by DR. ARTHUR MINKS. Berlin, 1896. pp. 247, 8vo.—Early in 1896, Dr. Minks gave a preliminary account in the Oester. Bot. Zeit. of what he terms “eine neue Lebensgemeinschaft.” The present volume gives a detailed account of his discovery. The discovery may perhaps better be styled an invention, for the name protrophie designates a condition previously recognized in certain lichens, as *Biatora intumescens*, by which they at first exist in a parasitic condition on other lichens and, after destroying them, lead an independent existence. To this condition Malme, who is a Schwendenerite, gave the name of Antagonistic Symbiosis. Minks, who is far from being a Schwendenerite, calls it Protrophie. By those who do not feel called upon to advocate any particular hypothesis, it might be supposed that it would be as well to speak of it simply as a case of parasitism, and in some, at least, of the cases cited by Minks the inquiry seems pertinent whether the protrophic plants should not be called fungi rather than lichens. On that point, however, discussion is out of the question, because what is or is not a lichen is a point on which lichenologists and mycologists have never been able to agree. W. G. F.

7. *The supposed great Octopus of Florida; certainly not a Cephalopod*.—Additional facts have been ascertained and specimens received, that render it quite certain that this remarkable structure is not the body of a Cephalopod. It was described by me, in the February number of this Journal, as the body of an Octopus,* from the examination of a number of photographs, and the statement made to me that, when it was first cast ashore, stumps of arms were found adherent to one end, one of which was said to have been 36 feet long.† Subsequently, when it was excavated and moved, this statement proved to be erroneous. Apparently nothing that can be called stumps of arms, or any other appendages, were present. Folds of the integument and muti-

* Many other zoölogists who examined the photographs held the same opinion. Some of those who have seen the samples of integument sent to me still believe that the specimen may be the body of some unknown genus of Cephalopods, allied to *Octopus*. But the thick integument of a Cephalopod is necessarily muscular and highly contractile, while in this creature it is elastic and resistant, and not at all contractile. Therefore I cannot refer it to that group, after having examined this structure.

† The following is the written statement, made by Mr. Wilson to Dr. Webb, in regard to the “arms” that he found when it first went ashore: “One arm was lying west of body, 23 feet long; one stump of arm, west of body, about 4 feet; three arms lying south of body and from appearances attached to same (although I did not dig quite to body, as it laid well down in the sand, and I was very tired), longest one measured over 32 feet; the other arms were 3 to 5 feet shorter.” Soon after this examination the specimen went adrift in another severe storm and was again cast ashore two miles farther south, which will probably account for the loss of these supposed arms.

lated and partly detached portions may have been mistaken for such structures. No bones or other hard parts were found in it.

Dr. Webb has recently sent to me several large masses of the integument of the creature, preserved fairly well in formalin. These masses are from 3 to 10 inches thick, and instead of being muscular, as had been thought, they have a structure similar to the hard, elastic variety of blubber-like integument found on the head of certain cetaceans, such as the sperm whale. They contain very little oil and cannot be called true blubber. They are firm, very tough and elastic, and composed mainly of much interlaced fibers and large bundles of tough, fibrous, white connective tissue. They are difficult to cut or tear apart, especially where indurated by partial drying. Some large irregular canals permeate the inner and less dense portions of the thick masses. These may have contained blood vessels originally. From the inner surface of some of the pieces large cords of elastic fibers proceeded inward. These now hang loosely from the masses of integument. Dr. Webb states that these were found attached on all sides to a long saccular organ, which occupied most of the central cavity of the great mass. No muscular fibers were present in the specimens sent. Perhaps the muscular tissues of the inner surfaces, if any were present originally, have decayed, but the tough fibrous mass does not show much decomposition. The outer surface shows in some places a tough, thin, gray, rather rough skin-like layer, that may be the remains of the outer skin. It looks a little like the skin of some fishes from which the scales have been removed. From these facts I am led to believe that the mass cast ashore is only a fragment, probably from the head, of some huge vertebrate animal, covered with a blubber-like layer of great thickness.

Although such an integument might, perhaps, be supposed compatible with the structure of some unknown fish* or reptile, it is certain that it is more like the integument found upon the upper part of the head of a sperm whale than anything else that I know. If we could imagine a sperm whale with the head prolonged far forward in the form of a great blunt, saccular snout, freely projecting beyond the upper jaw, and with a great central cavity, it might, if detached and eroded by the surf, present an appearance something like the mass cast ashore. It hardly seems possible, however, that the abruptly truncated and narrow snout of the common sperm whale could take on, even after being long tossed about by the waves, a form like this. No whaler who has seen it has recognized it as any part of a whale. It does not seem possible to identify such a large, hollow, pear-shaped sac, 21 feet long, with any part of an ordinary sperm whale unless its nose had become enlarged and distorted by disease, or possibly by extreme old age. No blowhole was discovered.

The specimen has now been moved several miles nearer to St. Augustine and enclosed by a fence to protect it from the drifting sand. It is likely to remain in nearly its present state for several months more.

A. E. VERRILL.

* The integument of *Orthogoriscus mola*, the great sun-fish, is very thick and elastic, but unlike this in structure.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Lehrbuch der Allgemeinen Chemie*; von DR. WILH. OSTWALD. Second edition, vol. ii. Part ii. Verwandschaftslehre. pp. 1-208 (Engelmann, Leipzig), 1896.—The present issue, the first of five installments, which when complete will conclude the present edition of the work, is devoted almost entirely to the history of affinity. Hardly anything remains of the previous edition except the arrangement. The whole work has been rewritten and numerous valuable additions in the shape of extracts from original memoirs have been inserted. Considerable space has been devoted to the work of Gibbs and van't Hoff, conspicuously marking the recent achievements in this branch of science, and the dissociation theory of Arrhenius receives its share of attention. The work comprises our complete knowledge of the doctrine of affinity, and is, like all other books from the pen of this talented author, a most valuable addition to scientific literature.

B. B. B.

2. *Inorganic Chemical Preparations*; by F. H. THORP. 8vo, pp. 238. Boston, 1896 (Ginn & Co.).—This important branch of chemical instruction doubtless deserves to be taught more generally and fully than is the case at present, and new aids to carrying out such instruction should be welcomed. The book under consideration gives 100 preparations, with directions which are generally very full and satisfactory. Much useful information is given concerning reactions, molecular weights, specific gravities of solutions and the solubilities of the products, etc. The preparations selected are the salts most used in the laboratory as reagents, or those of commercial importance. The raw materials required are, with few exceptions, inexpensive.

The quantities recommended in the book seem, in many instances, larger than the facilities of most laboratories would warrant and larger than the student would need to become familiar with the compounds. The number of preparations, consisting merely of the purification of commercial salts and which give but little variety of chemical methods, seems to the reviewer to be unduly large; but many instructive preparations are introduced, and with a proper selection of these a very satisfactory course could be carried out with the aid of this book.

H. L. W.

3. *Tutorial Chemistry*. Part i. Non-metals; by G. H. BAILEY. 12 mo, pp. 126. London (W. B. Clive; Hinds & Noble, 4 Cooper Institute, New York).—This little text-book possesses many admirable features. It is not overburdened with either facts or theory, but the fundamental principles of the science are clearly set forth and the number of facts presented seems well adapted for the needs of the beginner. The experiments, about 100 in all, are well chosen, and many of them show originality in their manner of presentation. A treatment of the subject of "chemical physics" is promised for the second part in connection with a study of the metals.

H. L. W.

4. *Laboratory Manual of Inorganic Chemistry*; by R. P.

WILLIAMS. Ninth edition, 12 mo, pp. 100. Boston, 1896 (Ginn & Co.).—This little book, intended for young pupils, gives one-hundred exercises, to each of which a page of the book is devoted, a blank page being left opposite to this for notes. A short course in qualitative analysis is included. The directions given for experiments are generally clear and illustrated by appropriate cuts. The text is considerably marred by the use of many abbreviations, all of which are not self-evident. Pupils using this book would require much aid from their teacher, as equations are continually required although none are given in the book. H. L. W.

5. *Mountain Observatories in America and Europe*; by EDWARD S. HOLDEN, Director of the Lick Observatory. 77 pp. with 25 plates. Washington, 1896. (Smithsonian Miscellaneous Collections, 1035).—This is a very interesting discussion of the conditions required for successful astronomical work at high altitudes, followed by an account of the chief observatories already established in different parts of the world. The highest of these is the observatory of M. Janssen on the summit of Mt. Blanc, at an altitude of 15,780 feet. These accounts are illustrated by a large number of excellent and interesting plates.

6. *Essays by George John Romanes*, edited by C. LLOYD MORGAN. pp. 253 (Longmans, Green & Co.). 1897.—The republication of these essays, which originally appeared in several of the English and American reviews, will recall the versatile and attractive style of Romanes. The essays deal mainly with the philosophical aspects of biology; they are worth gathering in this permanent shape because of the importance of the problems, which the author handled with rare skill. H. S. W.

7. *North American Birds*, by H. NEHRLING, with thirty-six colored plates after water-color paintings by Prof. Robert Ridgway, Washington, Prof. Goering, Leipzig, and Gustav Mutzel, Berlin. pp. 337-452, Milwaukee, Wis. (Geo. Brumder).—Part xvi completes this attractive work, to which attention has been repeatedly called hitherto. It is devoted to humming-birds, wood-peckers, kingfishers, etc., and closes with a list of plates and a general index.

8. *Das Klima von Frankfurt am Main*; im Auftrage des physikalischen Vereins bearbeitet von Dr. JULIUS ZIEGLER und Professor Dr. WALTER KÖNIG.—This is an exhaustive discussion of the meteorological conditions at Frankfurt. It is accompanied by many tables, giving observations of barometric pressure, temperature, precipitation, winds, etc., extending over the period of the last fifty years. The most important of these results are also presented in graphical form in a series of ten plates.

OBITUARY.

Professor JAMES JOSEPH SYLVESTER, the eminent English mathematician, from 1876 to 1883 Professor at the Johns Hopkins University, Baltimore, died in London on March 15th, in his eighty-third year.

BEAUTIFUL NEW MINERALS.



We have had an experienced collector traveling for us in California, Arizona and New Mexico for nearly three months, and we have now in stock many beautiful minerals which he secured and others will be announced next month.

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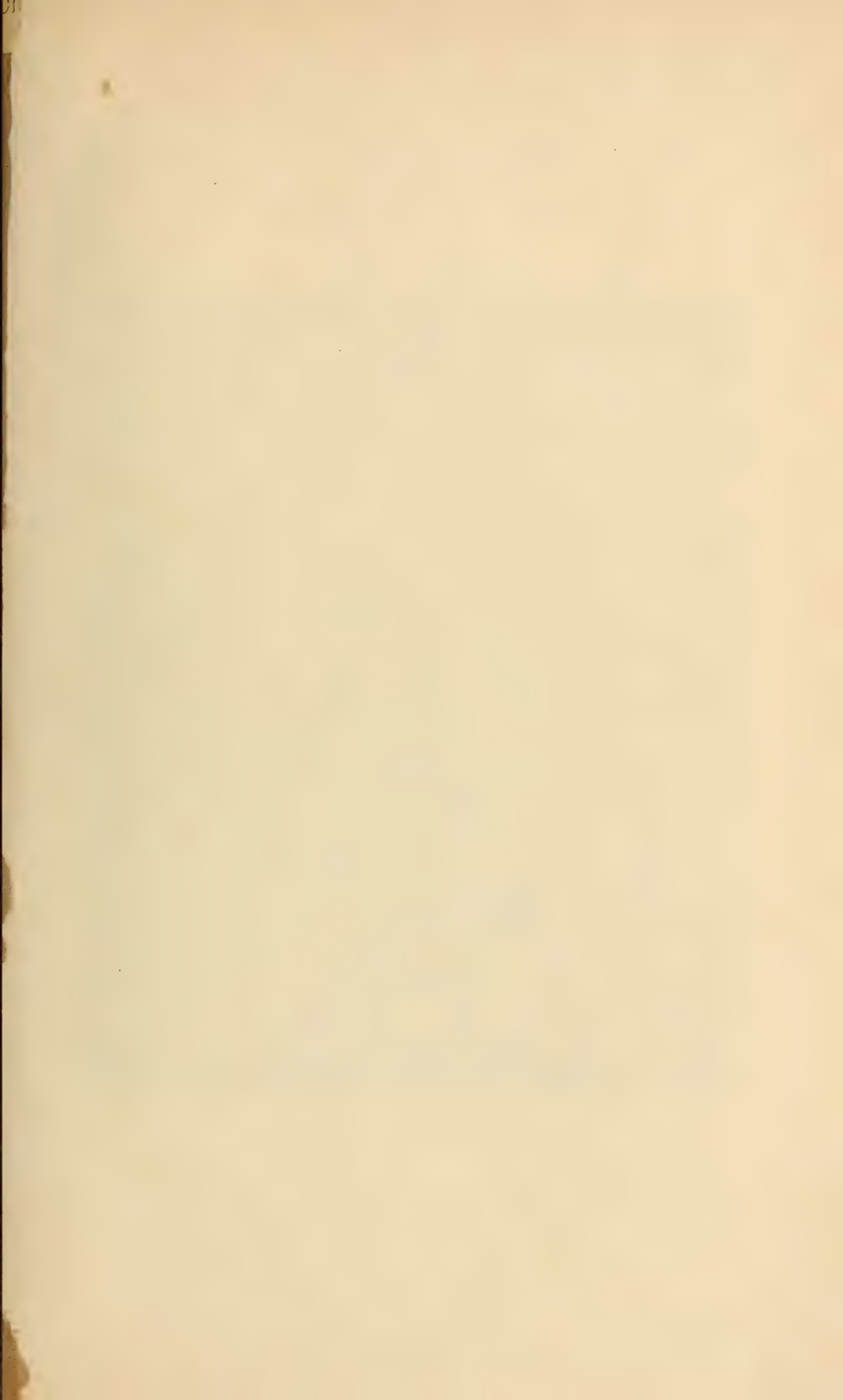
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THE

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[FOURTH SERIES.]

HUBERT ANSON NEWTON.

[Read before the National Academy of Sciences, in April, 1897.—The portrait accompanying this notice is a reproduction of a photograph taken by a member of the family in the spring of 1894.]

HUBERT ANSON NEWTON was born on March 19th, 1830, at Sherburne, N. Y., and died at New Haven, Conn., on the 12th day of August, 1896. He was the fifth son of a family of seven sons and four daughters, children of William and Lois (Butler) Newton. The parents traced their ancestry back to the first settlers of Massachusetts and Connecticut,* and had migrated from the latter to Sherburne, when many parts of central New York were still a wilderness. They both belonged to families remarkable for longevity, and lived themselves to the ages of ninety-three and ninety-four years. Of the children, all the sons and two daughters were living as recently as the year 1889, the youngest being then fifty-three years of age. William Newton was a man of considerable enterprise, and undertook the construction of the Buffalo section of the Erie canal, as well as other work in canal and railroad construction in New York and Pennsylvania. In these constructions he is said to have relied on his native abilities to think out for himself the solution of problems which are generally a matter of technical training. His wife was remarkable for great strength of character united with a quiet temperament and well-balanced mind, and was noted among her neighbors for her mathematical powers.

* Richard Butler, the great-grandfather of Lois Butler, came over from England before 1633, and was one of those who removed from Cambridge to Hartford. An ancestor of William Newton came directly from England to the New Haven colony about the middle of the same century.

Young Newton, whose mental endowments were thus evidently inherited, and whose controlling tastes were manifested at a very early age, fitted for college at the schools of Sherburne, and at the age of sixteen entered Yale College in the class graduating in 1850. After graduation he pursued his mathematical studies at New Haven and at home, and became tutor at Yale in January, 1853, when on account of the sickness and death of Professor Stanley the whole charge of the mathematical department devolved on him from the first.

In 1855, he was appointed professor of mathematics at the early age of twenty-five. This appointment testifies to the confidence which was felt in his abilities, and is almost the only instance in which the Yale Corporation has conferred the dignity of a full professorship on so young a man.

This appointment being accompanied with a leave of absence for a year, in order to give him the opportunity to study in Europe, it was but natural that he should be attracted to Paris, where Chasles was expounding at the Sorbonne that modern higher geometry of which he was to so large an extent the creator, and which appeals so strongly to the sense of the beautiful. And it was inevitable that the student should be profoundly impressed by the genius of his teacher, and by the fruitfulness and elegance of the methods which he was introducing. The effect of this year's study under the inspiring influence of such a master is seen in several contributions to the *Mathematical Monthly* during its brief existence in the years 1858-61. One of these was a problem which attracted at once the attention of Cayley, who sent a solution. Another was a discussion of the problem "to draw a circle tangent to three given circles," remarkable for his use of the principle of inversion. A third was a very elaborate memoir on the construction of curves by the straight edge and compasses, and by the straight edge alone. These early essays in geometry show a mind thoroughly imbued with the spirit of modern geometry, skilful in the use of its methods, and eager to extend the bounds of our knowledge.

Nevertheless, although for many years the higher geometry was with him a favorite subject of instruction for his more advanced students, either his own preferences, or perhaps rather the influence of his environment, was destined to lead him into a very different field of research. In the attention which has been paid to astronomy in this country we may recognize the history of the world repeating itself in a new country in respect to the order of the development of the sciences, or it may be enough to say that the questions which nature forces on us are likely to get more attention in a new country and a bustling age, than those which a reflective mind

puts to itself, and that the love of abstract truth which prompts to the construction of a system of doctrine, and the refined taste which is a critic of methods of demonstration, are matters of slow growth. At all events, when Professor Newton was entering upon his professorship, the study of the higher geometry was less consonant with the spirit of the age in this country than the pursuit of astronomical knowledge, and the latter sphere of activity soon engrossed his best efforts.

Yet it was not in any of the beaten paths of astronomers that Professor Newton was to move. It was rather in the wilds of a *terra incognita*, which astronomers had hardly troubled themselves to claim as belonging to their domain, that he first labored to establish law and order. It was doubtless not by chance that he turned his attention to the subject of shooting stars. The interest awakened in this country by the stupendous spectacle of 1833, which was not seen in Europe, had not died out, as is abundantly shown by inspection of the indexes of this Journal. This was especially true at New Haven, where Mr. Edward C. Herrick was distinguished for his indefatigable industry both in personal observation and in the search for records of former showers. A rich accumulation of material was thus awaiting development. In 1861, the Connecticut Academy of Arts and Sciences appointed a committee "to communicate with observers in various localities for combined and systematic observations upon the August and November meteors." In this committee Professor Newton was preëminently active. He entered zealously upon the work of collecting material by personal observation and correspondence and by organizing corps of observers of students and others, and at the same time set himself to utilize the material thus obtained by the most careful study. The value of the observations collected was greatly increased by a map of the heavens for plotting meteor-paths, which was prepared by Professor Newton and printed at the expense of the Connecticut Academy for distribution among observers.

By these organized efforts, in a great number of cases, observations were obtained on the same meteor as seen from different places, and the actual path in the atmosphere was computed by Professor Newton. In a paper published in 1865* the vertical height of the beginning and the end of the visible part of the path is given for more than one hundred meteors observed on the nights of August 10th and November 13th, 1863. It was shown that the average height of the November meteors is fifteen or twenty miles higher than that of the August meteors, the former beginning in the mean at a height of ninety-six miles and ending at sixty-one, the latter beginning at seventy and ending at fifty-six.

* This Journal, II, vol xl, p. 250.

We mention this paper first, because it seems to represent the culmination of a line of activity into which Professor Newton had entered much earlier. We must go back to consider other papers which he had published in the mean time.

His first papers on this subject, 1860-62,* were principally devoted to the determination of the paths and velocities of certain brilliant meteors or fireballs, which had attracted the attention of observers in different localities. Three of these appeared to have velocities much greater than is possible for permanent members of the solar system. To another a particular interest attached as belonging to the August shower, although exceptional in size. For this he calculated the elements of the orbit which would give the observed path and velocity. But the determination of the velocity in such cases, which depends upon the estimation by the observers of the time of flight, is necessarily very uncertain, and at best affords only a lower limit for the value of the original velocity of the body before it encountered the resistance of the earth's atmosphere. This would seem to constitute an insuperable difficulty in the determination of the orbits of meteoroids, to use the term which Professor Newton applied to these bodies, before they enter the earth's atmosphere to appear for a moment as luminous meteors. Yet it has been completely overcome in the case of the November meteors or Leonids, as they are called from the constellation from which they appear to radiate. This achievement constitutes one of the most interesting chapters in the history of meteoric science, and gives the subject an honorable place among the exact sciences.

In the first place, by a careful study of the records, Professor Newton showed that the connection of early showers with those of 1799 and 1833 had been masked by a progressive change in the time of the year in which the shower occurs. This change had amounted to a full month between A. D. 902, when the shower occurred on October 13, and 1833, when it occurred on November 13. It is in part due to the precession of the equinoxes, and in part to the motion of the node where the earth's orbit meets that of the meteoroids. This motion must be attributed to the perturbations of the orbits of the meteoroids which are produced by the attractions of the planets, and being in the direction opposite to that of the equinoxes, Professor Newton inferred that the motion of the meteoroids must be retrograde.

The showers do not, however, occur whenever the earth passes the node, but only when the passage occurs within a year or two before or after the termination of a cycle of 33.25 years. This number is obtained by dividing the interval between the

* This Journal, II, xxx, p. 186; xxxii, p. 448; and xxxiii, p. 338.

showers of 902 and 1833 by 28, the number of cycles between these dates, and must therefore be a very close approximation. For if these showers did not mark the precise end of cycles, the resultant error would be divided by 28. Professor Newton showed that this value of the cycle requires that the number of revolutions performed by the meteoroids in one year should be either $2 \pm \frac{1}{33.25}$ or $1 \pm \frac{1}{33.25}$ or $\frac{1}{33.25}$. In other words, the periodic time of the meteoroids must be either 180.0 or 185.4 or 354.6 or 376.6 days, or 33.25 years. Now the velocity of any body in the solar system has a simple relation to its periodic time and its distance from the sun. Assuming, therefore, any one of these five values of the periodic time, we have the velocities of the Leonids at the node very sharply determined. From this velocity, with the position of the apparent radiant, which gives the direction of the relative motion, and with the knowledge that the heliocentric motion is retrograde, we may easily determine the orbit.

We have, therefore, five orbits from which to choose. The calculation of the secular motion of the node due to the disturbing action of the planets, would enable us to decide between these orbits.

Such are the most important conclusions which Professor Newton derived from the study of these remarkable showers, interesting not only from the magnificence of the spectacle occasionally exhibited, but in a much higher degree from the peculiarity in the periodic character of their occurrence, which affords the means of the determination of the orbit of the meteoroids with a precision which would at first sight appear impossible.

Professor Newton anticipated a notable return of the shower in 1866, with some precursors in the years immediately preceding, a prediction which was amply verified. In the mean time he turned his attention to the properties which belong to shooting stars in general, and especially to those average values which relate to large numbers of these bodies not belonging to any particular swarm.

This kind of investigation Maxwell has called *statistical*, and has in more than one passage signalized its difficulties. The writer recollects a passage of Maxwell which was pointed out to him by Professor Newton, in which the author says that serious errors have been made in such inquiries by men whose competency in other branches of mathematics was unquestioned. Doubtless Professor Newton was very conscious of the necessity of caution in these inquiries, as is indeed abundantly evident from the manner in which he expressed his conclusions; but the writer is not aware of any passage in which he has afforded an illustration of Maxwell's remark.

The results of these investigations appeared in an elaborate memoir "On Shooting Stars," which was read to the National Academy in 1864, and appeared two years later in the *Memoirs of the Academy*.^{*} An abstract was given in this *Journal* in 1865.[†] The following are some of the subjects treated, with some of the more interesting results :

The distribution of the apparent paths of shooting stars in azimuth and altitude.

The vertical distribution of the luminous part of the real paths. The value found for the mean height of the middle point of the luminous path was a trifle less than sixty miles.

The mean length of apparent paths.

The mean distance of paths from the observer.

The mean foreshortening of paths.

The mean length of the visible part of the real paths.

The mean time of flight as estimated by observers.

The distribution of the orbits of meteoroids in the solar system.

The daily number of shooting stars, and the density of the meteoroides in the space which the earth traverses. The average number of shooting stars which enter the atmosphere daily, and which are large enough to be visible to the naked eye, if the sun, moon and clouds would permit it, is more than seven and a half millions. Certain observations with instruments seem to indicate that this number should be increased to more than four hundred millions, to include telescopic shooting stars, and there is no reason to doubt that an increase of optical power beyond that employed in these observations would reveal still larger numbers of these small bodies. In each volume of the size of the earth, of the space which the earth is traversing in its orbit about the sun, there are as many as thirteen thousand small bodies, each of which is such as would furnish a shooting star visible under favorable circumstances to the naked eye.

These conclusions are certainly of a startling character, but not of greater interest than those relating to the velocity of meteoroids. There are two velocities to be considered, which are evidently connected, the velocity relative to the earth, and the velocity of the meteoroids in the solar system. To the latter, great interest attaches from the fact that it determines the nature of the orbit of the meteoroid. A velocity equal to that of the earth, indicates an orbit like that of the earth; a velocity $\sqrt{2}$ times as great, a parabolic orbit like that of most comets, while a velocity greater than this indicates a hyperbolic orbit.

Professor Newton sought to form an estimate of this critical quantity in more than one way. That on which he placed

^{*} Vol. i, 3d memoir.

[†] II, xxxix, 193.

most reliance was based on a comparison of the numbers of shooting stars seen in the different hours of the night. It is evident that in the morning, when we are in front of the earth in its motion about the sun, we should see more shooting stars than in the evening, when we are behind the earth; but the greater the velocity of the meteoroids compared with that of the earth, the less the difference would be in the numbers of evening and morning stars.*

After a careful discussion of the evidence Professor Newton reached the conclusion that "we must regard as almost certain (on the hypothesis of an equable distribution of the directions of absolute motions), that the mean velocity of the meteoroids exceeds considerably that of the earth; that the orbits are not approximately circular, but resemble more the orbits of comets."

This last sentence, which is taken from the abstract published in this Journal in 1865, and is a little more definitely and positively expressed than the corresponding passage in the original memoir, indicating apparently that the author's conviction had been growing more positive in the interval, or at least that the importance of the conclusion had been growing upon him, embodies what is perhaps the most important result of the memoir, and derives a curious significance from the discoveries which were to astonish astronomers in the immediate future.

The return of the November or Leonid shower in 1865, and especially in 1866, when the display was very brilliant in Europe, gave an immense stimulus to meteoric study, and an especial prominence to this group of meteoroids. "Not since the year 1759," says Schiaparelli, "when the predicted return of a comet first took place, had the verified prediction of a periodic phenomenon made a greater impression than the magnificent spectacle of November, 1866. The study of cosmic meteors thereby gained the dignity of a science, and took finally an honorable place among the other branches of astronomy."† Professor J. C. Adams, of Cambridge, England, then took up the calculation of the perturbations determining the motion of the node. We have seen that Professor Newton had shown that the periodic time was limited to five sharply determined values, each of which with the other data would

* It may not be out of place to notice here an erratum which occurs both in the *Memoirs of the National Academy* and in the abstract in this Journal, and which the writer finds marked in a private copy of Professor Newton's. In the table on page 20 of the memoir and page 206 of the abstract, the column of numbers under the head "hour of the night" should be inverted. There is another displacement in the table in the memoir, which is, however, corrected in the abstract.

† Schiaparelli, *Entwurf einer astronomischen Theorie der Sternschnuppen*, p. 55.

give an orbit, and that the true orbit could be distinguished from the other four by the calculation of the secular motion of the node.

Professor Adams first calculated the motion of the node due to the attractions of Jupiter, Venus, and the Earth for the orbit having a period of 354.6 days. This amounted to a little less than 12' in 33.25 years. As Professor Newton had shown that the dates of the showers require a motion of 29' in 33.25 years, the period of 354.6 days must be rejected. The case would be nearly the same with a period of 376.6 days, while a period of 180 or 185.4 days would give a still smaller motion of the node. Hence, of the five possible periods indicated by Professor Newton, four were shown to be entirely incompatible with the motion of the node, and it only remained to examine whether the fifth period, viz: that of 33.25 years, would give a motion of the node in accordance with the observed value. As this period gives a very long ellipse for the orbit, extending a little beyond the orbit of Uranus, it was necessary to take account of the perturbations due to that planet and to Saturn. Professor Adams found 28' for the motion of the node. As this value must be regarded as sensibly identical with Professor Newton's 29' of observed motion, no doubt was left in regard to the period of revolution or the orbit of the meteoroids.*

About this time, M. Schiaparelli was led by a course of reasoning similar to Professor Newton's to the same conclusion,—that the mean velocity of the meteoroids is not very different from that due to parabolic orbits. In the course of his speculations in regard to the manner in which such bodies might enter the solar system, the questions suggested themselves: whether meteoroids and comets may not have a similar origin; whether, in case a swarm of meteoroids should include a body of sufficient size, this would not appear as a comet; and whether some of the known comets may not belong to streams of meteoroids. Calculating the orbit of the Perseids, or August meteoroids, from the radiant point, with the assumption of a nearly parabolic velocity, he found an orbit very similar to that of the great comet of 1862, which may therefore be considered as one of the Perseids,—probably the largest of them all.†

At that time no known cometic orbit agreed with that of the Leonids, but a few months later, as soon as the definitive elements of the orbit of the first comet of 1866 were published, their resemblance to those of the Leonids, as calculated for the period of 33.25 years, which had been proved to be the correct

* Monthly Notices Roy. Ast. Soc., vol. xxvii, p. 247.

† Entwurf, etc., pp. 49–54.

value, was strikingly manifested, attracting at once the notice of several astronomers.

Other relations of the same kind have been discovered later, of which that of Biela's comet and the Andromeds is the most interesting, as we have seen the comet breaking up under the influence of the sun; but in no case is the coincidence so striking as in that of the Leonids, since in no other case is the orbit of the meteoroids completely known, independently of that of the comet, and without any arbitrary assumption in regard to their periodic time.

The first comet of 1866 is probably not the only one belonging to the Leonid stream of meteoroids. Professor Newton has remarked that the Chinese annals mention two comets which passed rapidly in succession across the sky in 1366, a few days after the passage of the earth through the node of the Leonid stream, which was marked in Europe by one of the most remarkable star-showers on record. The course of these comets, as described by the annalists, was in the line of the Leonid stream.*

This identification of comets with meteors or shooting-stars marks an epoch in the study of the latter. Henceforth, they must be studied in connection with comets. It was presumably this discovery which led Professor Newton to those statistical investigations respecting comets, which we shall presently consider. At this point, however, at the close as it were of the first chapter in the history of meteoric science, it seems not unfitting to quote the words of an eminent foreign astronomer, written about this time, in regard to Professor Newton's contributions to this subject. In an elaborate memoir in the *Comptes Rendus*, M. Faye says, with reference to our knowledge of shooting-stars and their orbits, "we may find in the works of M. Newton, of the United States, the most advanced expression of the state of science on this subject, and even the germ, I think, of the very remarkable ideas brought forward in these last days by M. Schiaparelli and M. Le Verrier."†

The first fruit of Professor Newton's statistical studies on comets appeared in 1878 in a paper "On the Origin of Comets." In this paper he considers the distribution in the solar system of the known cometic orbits, and compares it with what we might expect on either of two hypotheses: that of Kant, that the comets were formed in the evolution of the solar system from the more distant portion of the solar nebula; and that of Laplace, that the comets have come from the stellar spaces and in their origin had no relation to the solar system.

* This Journal II, xliii, p. 298, and xlv, p. 91, or *Encycl. Britann.*, article Meteor.

† *Comptes Rendus*, T. lxiv, p. 551.

In regard to the distribution of the aphelia, he shows that, except so far as modified by the perturbations due to the planets, the theory of internal origin would require all the aphelia to be in the vicinity of the ecliptic,—the theory of external origin would make all directions of the aphelia equally probable, *i. e.*, the distribution in latitude of the aphelia should be that in which the frequency is as the cosine of the latitude. The actual distribution comes very near to this, but as the effect of perturbations would tend to equalize the distribution of aphelia in all directions, Professor Newton does not regard this argument as entirely decisive. He remarks, however, that if Kant's hypothesis be true, the comets must have been revolving in their orbits a very long time, and the process of the disintegration of comets must be very slow.

In regard to the distribution of the orbits in inclination, the author shows that the theory of internal origin would make all inclinations equally probable,—the theory of external origin would make all directions of the normal to the plane of the orbit equally probable. On the first hypothesis, therefore, we should expect a uniform distribution in inclination; on the second, a frequency proportioned to the sine of the inclination. It was shown by a diagram in which the actual and the two theoretical distributions are represented graphically, that the actual distribution agrees pretty well with the theory of external origin and not at all with that of internal origin. It was also shown that the curve of actual distribution cannot be made to agree with Kant's hypothesis by any simple and reasonable allowances for perturbations. On the other hand, if we assume the external origin of comets, and ask how the curve of sines must be modified in order to take account of perturbations, it is shown that the principal effect will be to increase somewhat the number of inclinations between 90° and 135° at the expense of those between 45° and 90° . It is apparent at once from the diagram that such a change would make a very good agreement between the actual and theoretical curves, the only important difference remaining being due to comets of short periods, which mostly have small inclinations with direct motion. These should not weigh very much, the author observes, in the general question of the distribution of inclinations, because they return so frequently and are so easily detected that their number in a list of observed comets is out of all proportion to their number among existing comets. But this group of comets of short periods can easily be explained on the theory of an external origin. For such comets must have lost a large part of their velocity by the influence of a planet. This is only likely to happen when a comet overtakes the planet and passes in front of it. This implies that its orig-

inal motion was direct and in an orbit of small inclination to that of the planets, and although it may lose a large part of its velocity, its motion will generally remain direct and in a plane of small inclination. This very interesting case of the comets of short periods and small inclinations, which was treated rather briefly in this paper, was discussed more fully by Professor Newton at the meeting of the British Association in the following year.*

Many years later, Professor Newton returned to the same general subject in a very interesting memoir "On the Capture of Comets by Planets; especially their Capture by Jupiter," which was read before the National Academy in 1891, and appeared in the *Memoirs of the Academy* two years later.† It also appeared in this *Journal* in the year in which it was read.‡ This contains the results of careful statistical calculations on the effect of perturbations on orbits of comets originally parabolic. It corroborates the more general statements of the paper "On the Origin of Comets," giving them a precise quantitative form. One or two quotations will give some idea of the nature of this very elaborate and curious memoir, in which, however, the results are largely presented in the form of diagrams.

On a certain hypothesis regarding an original equable distribution of comets in parabolic orbits about the sun, it is shown that "if in a given period of time a thousand million comets come in parabolic orbits nearer to the sun than Jupiter, 126 of them will have their orbits changed" by the action of that planet "into ellipses with periodic times less than one-half that of Jupiter; 839 of them will have their orbits changed into ellipses with periodic times less than that of Jupiter; 1701 of them will have their orbits changed into ellipses with periodic times less than once and a half that of Jupiter, and 2670 of them will have their orbits changed into ellipses with periodic times less than twice that of Jupiter." A little later, Professor Newton considers the question, which he characterizes as perhaps more important, of the direct or retrograde motion of the comets after such perturbations. It is shown that of the 839 comets which have periodic times less than Jupiter, 203 will have retrograde motions, and 636 will have direct motions. Of the 203 with retrograde motion, and of the 636 with direct motion, 51 and 257, respectively, will have orbits inclined less than 30° to that of Jupiter.

We have seen that the earliest of Professor Newton's more important studies on meteors related to the Leonids, which at

* Rep't Brit. Assoc. Adv. Sci. for 1879, p. 272.

† Mem. Nat. Acad., vol. vi, 1st memoir.

‡ This *Journal*, III, xlii, pp. 183 and 482.

that time far surpassed all other meteoric streams in interest. One of his later studies related to another stream which in the mean time had acquired great importance. The identification of the orbit of the Andromed meteors with that of Biela's comet, which we have already mentioned, gave these bodies a unique interest, as the comet had been seen to break up under the influence of the sun. Here the evolution of meteoroids was taking place before our eyes; and this interest was heightened by the showers of 1872 and 1885, which in Europe seem to have been unsurpassed in brilliancy by any which have occurred in this century.

The phenomena of each of these showers were carefully discussed by Professor Newton. Among the principal results of his paper on the latter shower are the following:*

The time of the maximum frequency of meteors was Nov. 27, 1885, 6^h 15^m Gr. m. t. The estimated number per hour visible at one place was then 75,000. This gives a density of the meteoroids in space represented by one to a cube of twenty miles edge. Three hours later the frequency had fallen to one-tenth of the maximum value. The really dense portion of the stream through which we passed was less than 100,000 miles in thickness, and nearly all would be included in a thickness of 200,000 miles.

A formula is given to express the effect of the earth's attraction on the approaching meteoroids in altering the position of the radiant. This is technically known as the zenithal attraction, and is quite important in the case of these meteors on account of their small relative velocity. The significance of the formula may be roughly expressed by saying that the earth's attraction changes the radiant of the Biela meteors, toward the vertical of the observer, one-tenth of the observed zenith distance of the radiant, or more briefly, that the zenithal attraction for these meteors is one-tenth of the observed zenith distance. The radiant even after the correction for zenithal attraction, and another for the rotation of the earth on its axis, is not a point but an area of several degrees diameter. The same has been observed in regard to other showers, but the result comes out more distinctly in the present case because the meteors were so numerous and the shower so carefully observed.

This implies a want of parallelism in the paths of the meteors, and it is a very important question whether it exists before the meteoroids enter our atmosphere, or whether it is due to the action of the atmosphere.

Professor Newton shows that it is difficult to account for so large a difference in the original motions of the meteoroids, and

* This Journal, III, xxxi, p. 409.

thinks it reasonable to attribute a large part of the want of parallelism to the action of the atmosphere on bodies of an irregular form, such as we have every reason to believe that the meteoroids have, when they enter our atmosphere. The effect of the heat generated will be to round off the edges and prominent parts, and to reduce the meteor to a form more and more spherical. It is, therefore, quite natural that the greater portion of the curvature of the paths should be in the invisible portion and thus escape our notice. It is only in exceptional cases that the visible path is notably curved.

But the great interest of the paper centers in his discussion of the relation of this shower to preceding showers, and to the orbit of Biela's comet. The changes in the date of the shower (from Dec. 6 to Nov. 27) and in the position of the radiant are shown to be related to the great perturbations of Biela's comet in 1794, 1831, and 1841-2. The showers observed by Brandes, Dec. 6th, 1798, by Herrick, Dec. 7th, 1838, and by Heis, Dec. 8th and 10th, 1847, are related to the orbit of Biela's comet as it was in 1772; while the great showers of 1872 and 1885, as well as a trifling display in 1867, are related to the orbit of 1852.*

Assuming, then, that the meteoroids which we met on the 27th of November, 1872, did not leave the immediate neighborhood of the Biela comet before 1841.5, we seem to have the data for a very precise determination of their orbit between those dates. The same is true of those which we met in 1885. The computation of these orbits, the author remarks, may possibly give evidence for or against the existence of a resisting medium in the solar system.

In his last public utterance on the subject of meteors, which was on the occasion of the recent sesquicentennial celebration of the American Philosophical Society, Professor Newton returns to the Biela meteoroids, and finds in the scattering which they show in the plane of their orbit the proof of a disturbing force in that plane, and therefore not due to the planets. The force exerted by the sun appears to be modified somewhat as we see it in the comet's tails, where indeed the attraction is changed into a repulsion. Something of the same sort on a smaller scale relatively to the mass of the bodies appears to modify the sun's action on the meteoroids.

In 1888 Professor Newton read a paper before the National Academy "Upon the relation which the former Orbits of those Meteorites that are in our collections, and that were seen

*It is a curious coincidence that the original discoverer of the December shower as a periodic phenomenon, Mr. Edward C. Herrick, should have been (with a companion, Mr. Francis Bradley,) the first to observe that breaking up of the parent body which was destined to reinforce the meteoric stream in so remarkable a manner. See this Journal, III, xxxi, pp. 85 and 88.

to fall, had to the Earth's Orbit." This was based upon a very careful study of more than 116 cases for which we have statements indicating more or less definitely the direction of the path through the air, as well as 94 cases in which we only know the time of the fall. The results are expressed in the following three propositions:

1. The meteorites which we have in our cabinets and which were seen to fall were originally (as a class, and with a very small number of exceptions) moving about the sun in orbits that had inclinations less than 90° ; that is, their motions were direct, not retrograde.

2. The reason why we have only this class of stones in our collections is not one wholly or even mainly dependent on the habits of men; nor on the times when men are out of doors; nor on the places where men live; nor on any other principle of selection acting at or after the arrival of the stones at the ground. Either the stones which are moving in the solar system across the earth's orbit move in general in direct orbits; or else for some reason the stones which move in retrograde orbits do not in general come through the air to the ground in solid form.

3. The perihelion distances of nearly all the orbits in which these stones moved were not less than 0.5 nor more than 1.0, the earth's radius vector being unity.

Professor Newton adds, that it seems a natural and proper corollary to these propositions (unless it shall appear that stones meeting the earth are destroyed in the air) that the larger meteorites moving in our solar system are allied much more closely with the group of comets of short period than with comets whose orbits are nearly parabolic. All the known comets of shorter periods than 33 years move about the sun in direct orbits that have moderate inclinations to the ecliptic. On the contrary, of the nearly parabolic orbits that are known only a small proportion of the whole number have small inclinations with direct motion.

We have briefly mentioned those papers which seem to constitute the most important contributions to the science of meteors and comets. To fully appreciate Professor Newton's activity in this field, it would be necessary to take account of his minor contributions. These are given in the annexed bibliography, where it will be seen that more than half of the entries relate to these subjects.

Most interesting and instructive to the general reader are his utterances on occasions when he has given a résumé of our knowledge on these subjects or some branch of them, as in the address "On the Meteorites, the Meteors, and the Shooting

Stars," which he delivered in 1886 as retiring president of the American Association for the Advancement of Science, or in certain lectures in the public courses of the Sheffield Scientific School of Yale University, entitled "The story of Biela's Comet" (1874), "The relation of Meteorites to Comets" (1876), "The Worship of Meteorites" (1889), or in the articles on Meteors in the *Encyclopædia Britannica* and Johnson's *Cyclopædia*.

If we ask what traits of mind and character are indicated by these papers, the answer is not difficult. Professor Klein has divided mathematical minds into three leading classes: the logicians, whose pleasure and power lies in subtlety of definition and dialectic skill; the geometers, whose power lies in the use of the space-intuitions; and the formalists, who seek to find an algorithm for every operation.* Professor Newton evidently belonged to the second of these classes, and his natural tastes seem to have found an equal gratification in the development of a system of abstract geometric truths, or in the investigation of the concrete phenomena of nature as they exist in space and time.

But these papers show more than the type of mind of the author; they give no uncertain testimony concerning the character of the man. In all these papers we see a love of honest work, an aversion to shams, a distrust of rash generalizations and speculations based on uncertain premises. He was never anxious to add one more guess on doubtful matters in the hope of hitting the truth, or what might pass as such for a time, but was always willing to take infinite pains in the most careful test of every theory. To these qualities was joined a modesty which forbade the pushing of his own claims, and desired no reputation except the unsought tribute of competent judges. At the close of his article on meteors in the *Encyclopædia Britannica*, which has not the least reference to himself as a contributor to the science, he remarks that "meteoric science is a structure built stone by stone by many builders." We may add that no one has done more than himself to establish the foundations of the science, and that the stones which he has laid are not likely to need relaying.

The value of Professor Newton's work has been recognized by learned societies and institutions both at home and abroad. He received the honorary degree of Doctor of Laws from the University of Michigan in 1868. He was president of the section of Mathematics and Astronomy in the American Association for the Advancement in Science in 1875, and president of the Association in 1885. On the first occasion he delivered an address entitled "A plea for the study of pure mathematics";

* Lectures on Mathematics (Evanston), p. 2.

on the second the address on Meteorites, etc., which we have already mentioned. Of the American Mathematical Society he was vice-president at the time of his death. In 1888 the J. Lawrence Smith gold medal was awarded to him by the National Academy for his investigations on the orbits of meteoroids. We may quote a sentence or two from his reply to the address of presentation, so characteristic are they of the man that uttered them: "To discover some new truth in nature," he said, "even though it concerns the small things in the world, gives one of the purest pleasures in human experience. It gives joy to tell others of the treasure found."

Besides the various learned societies in our own country of which he was a member, including the American Academy of Arts and Sciences from 1862, the National Academy of Sciences from its foundation in 1863, the American Philosophical Society from 1867, he was elected in 1872 Associate of the Royal Astronomical Society of London, in 1886 Foreign Fellow of the Royal Society of Edinburgh, and in 1892 Foreign Member of the Royal Society of London.

But the studies which have won for their author an honorable reputation among men of science of all countries, form only one side of the life of the man whom we are considering. Another side, probably the most important, is that in which he was identified with the organic life of the College and University with which he had been connected from a very early age. In fact, we might almost call the studies which we have been considering, the recreations of a busy life of one whose serious occupation has been that of an instructor. If from all those who have come under his instruction we should seek to learn their personal recollections of Professor Newton, we should probably find that the most universal impression made on his students was his enthusiastic love of the subject which he was teaching.

A department of the University in which he took an especial interest was the Observatory. This was placed under his direction at its organization, and although he subsequently resigned the nominal directorship, the institution remained virtually under his charge, and may be said to owe its existence in large measure to his untiring efforts and personal sacrifice in its behalf.

One sphere of activity in the Observatory was suggested by a happy accident which Professor Newton has described in this *Journal*, September, 1893. An amateur astronomer in a neighboring town, Mr. John Lewis, accidentally obtained on a stellar photograph the track of a large meteor. He announced in the newspapers that he had secured such a photograph, and requested observations from those who had seen its flight. The

photographic plate, with letters received from various observers, were placed in Professor Newton's hands, and were discussed in the paper mentioned. The advantages of photographic observations were so conspicuous that Professor Newton was anxious that the Observatory should employ this method of securing the tracks of meteors. With the aid of an appropriation granted by the National Academy from the income of the J. Lawrence Smith fund, a battery of cameras was mounted on an equatorial axis. By this means, a number of meteor-tracks have been obtained of the August meteors, and in one case, through a simultaneous observation by Mr. Lewis in Ansonia, Professor Newton was able to calculate the course of the meteor in the atmosphere with a probable error which he estimated at less than a mile. The results which may be expected at the now near return of the Leonids will be of especial interest, but it will be for others to utilize them.

Professor Newton was much interested in the collection of meteorites, and the fine collection of stones and irons in the Peabody Museum of Yale University owes much to his efforts in this direction.

Professor Newton was a member of the American Metrological Society from the first, and was conspicuously active in the agitation which resulted in the enactment of the law of 1866, legalizing the use of the metric system. He prepared the table of the metric equivalents of the customary units of weights and measures which was incorporated in the act, and by which the relations of the fundamental units were defined. But he did not stop here. Appreciating the weakness of legislative enactment compared with popular sentiment, and feeling that the real battle was to be won in familiarizing the people with the metric system, he took pains to interest the makers of scales and rulers and other devices for measurement in adopting the units and graduations of the metric system, and to have the proper tables introduced into school arithmetics.

He was also an active member of the Connecticut Academy of Arts and Sciences, serving several years both as secretary and president,—also as member of the council. He was associate editor of this Journal from 1864, having especial charge of the department of astronomy. His notes on observations of meteors and on the progress of meteoric science, often very brief, sometimes more extended, but always well considered, were especially valuable.

In spite of his studious tastes and love of a quiet life, he did not shirk the duties of citizenship, serving a term as alderman in the city council, being elected, we may observe, in a ward of politics strongly opposed to his own.

Professor Newton married, April 14th, 1859, Anna C., daughter of the Rev. Joseph C. Stiles, D. D., of Georgia, at one time pastor of the Mercer Street Presbyterian Church in New York City, and subsequently of the South Church in New Haven. She survived her husband but three months, leaving two daughters.

In all these relations of life, the subject of this sketch exhibited the same traits of character which are seen in his published papers, the same modesty, the same conscientiousness, the same devotion to high ideals. His life was the quiet life of the scholar, ennobled by the unselfish aims of the Christian gentleman; his memory will be cherished by many friends; and so long as astronomers, while they watch the return of the Leonids marking off the passage of the centuries, shall care to turn the earlier pages of this branch of astronomy, his name will have an honorable place in the history of the science.

J. WILLARD GIBBS.

PUBLISHED WRITINGS OF HUBERT A. NEWTON.

[Taken, with additions, from "Bibliographies of the present officers of Yale University, 1893."]

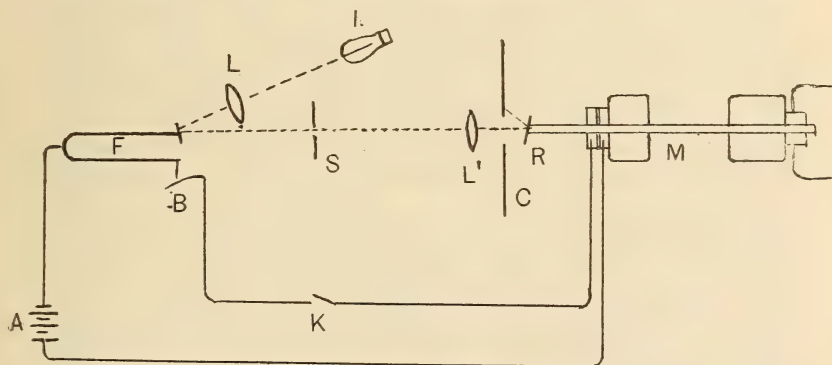
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ART. XXXV.—*On a means of producing a Constant Angular velocity*; by A. G. WEBSTER, PH.D.

IN many physical determinations one of the most important elements, and one of the most difficult to maintain constant, is a velocity of rotation. If the velocity is very small, and very little power is required to be transmitted, a clock-work device with some form of escapement is all that could be desired. If as much power is needed as is required to drive a large telescope or siderostat, however, the clockwork becomes expensive, and various governing devices other than escapements have to be employed, and the very great number of such devices actually in use shows how unsatisfactory the method must be. In electrical determinations in absolute measure, such as determinations of the ohm or of "*v*," clockwork is out of the question, as a high speed has to be kept up, and resort has generally been had to water or electrical motors, the speed being



governed by a special observer, who compared the angular velocity with the frequency of a tuning fork by some stroboscopic method. It has doubtless occurred to many that it would be possible to regulate an electric motor by an intermittent current interrupted directly by a tuning-fork, and such an arrangement, proposed by Marcel Deprez, is quoted as one of the earliest forms of synchronous motor. I am not aware whether the experiment was ever actually carried out; in any case no one seems to have made use of the device in practical cases where any amount of power was needed. At the Electrical Congress in Chicago in 1893 I read a short note on an arrangement that I had used, but as I have had a number of inquiries on the subject I think it may be worth while to publish the matter in a scientific journal.

Upon the shaft of a continuous current motor, M, are carried two armatures, one for the main driving current, the other, consisting of a continuous winding with collecting rings, for the auxiliary regulating current. In the motor generally used by the writer for this purpose, and intended for about one horse-power, the two armature windings are wound one over the other, and are in the same field. This is more compact than if two motors are connected together, and somewhat more convenient than if the second armature is replaced by ring connections at two points in the main armature, which is simpler. F is the controlling tuning fork, independently driven by a single storage cell. The auxiliary current, furnished by the storage-battery A, is led into the tuning-fork, through a platinum wire carried on one prong to a mercury break B, described in the next article, and then through a switch K to the brushes of the auxiliary armature. The synchronism is attained by means of the following arrangement. A mirror carried on one prong of the fork forms, by means of a lens L, an image of the filament of an incandescent lamp I, whose plane is horizontal, on a screen S. This screen has a narrow horizontal slit, which allows the beam of light to pass when the fork is nearly, but not exactly, in its equilibrium position. The beam then passes through a hole in a screen C, and being reflected from the mirror R, set obliquely on the shaft of the motor, forms by means of the lens L' a small bright image on the other side of the screen C. If the fork is at rest and the motor revolving, of course this spot is drawn out into a bright circle. If now the fork be set in motion, the beam of light is interrupted, and the circle is broken up into a large number of bright arcs, which revolve in one direction or the other, according to circumstances. As the speed of the motor increases, the number of arcs is successively reduced, until finally there are only two, when synchronism is nearly attained. The two arcs move first in the reverse direction to that of the motor, and as the speed increases, finally stand still, and then begin to move in the direct sense. By regulating the resistance in the field magnets of the motor, the spots may be made to stand still. We then have a convenient stroboscopic method suitable for regulation by hand in the ordinary manner. If at this point the auxiliary current is thrown on by the switch K, the regulation goes on of itself, and if the auxiliary current has been made of the proper strength, without further attention. Any fluctuations are shown by the oscillations of the two arcs about their mean positions, and by measuring the angle of oscillation and the time in which it is performed, the variation from constancy of the angular velocity may be determined. Of course the *mean* angular velocity

is constant to the limit of constancy of the frequency of the tuning-fork. The observer, being released from governing the rotation, is at liberty to determine this limit of constancy by comparing the fork with a standard by Lissajous's method. In this manner I found that it was not difficult to obtain an accuracy for the fork approaching one part in twenty thousand. The oscillation of the motor about this mean may be made, by means of a fly-wheel, very small.

In throwing on the auxiliary current it is of course necessary for the motor to have attained not only the proper velocity, but the proper phase. In order to determine this it is necessary to distinguish between the two bright spots, and this is the object of placing the slit S in an unsymmetrical position with respect to the vibration, so that the two arcs are not opposite each other. The proper position of the arcs for throwing on the current is determined by a few trials, and may be marked on the screen. In order to warn the observer of a violent oscillation, if he is not looking at the screen, a telephone may be placed in shunt with the brushes of the auxiliary armature, and will, if the synchronism fails, by its loud beats call the observer even from the next room. I believe a device of this sort has been patented by one of the great companies for the purpose of indicating the phase of alternators to be run in parallel—I presume it is possible to patent the use of a telephone for waking one in the morning, or anything else, but such an arrangement appears trivial,—it was used by me more than four years ago.

In order to test the method practically by the transmission of some power, two years ago I belted to the pulley of the motor a heavy cone-pulley running nicely on points, and that to the cone-pulley of a lathe of twelve inches swing. The lathe had a heavy fly-wheel for foot-power, which was belted to the pulley to take up the power and furnish a means of checking oscillations. A cord running over the intermediate cone pulley and carrying a number of weights furnished the means of absorbing most of the power. The motor was run by means of an Edison dynamo designed for 110 volts, but by means of resistance in the field the voltage was brought down, so that of course the regulation of the potential was not very good. The results therefore exhibit the method at its worst, while driving from a storage battery would give far better results. The frequency of the fork used was twenty-five per second. The gearing ran the lathe at at least twice its ordinary speed, the large treadle-pulley making 3.8 revolutions per second, and causing considerable vibration. In the first run the armature had 47 volts at the brushes, and 12 ampères. The governing current was then 1.9 ampères (mean intermittent).

The run of five minutes was reasonably steady, the oscillations being slow, and the greatest oscillation of the spot in the whole period being not over seventy degrees. Later the oscillations became worse, and then a complete to and fro oscillation of forty-five degrees on each side of the mean took place in eight seconds, corresponding to a maximum variation from the mean of one part in eight hundred. These were about the worst figures obtained. The next run of twenty-three minutes maintained the synchronism until the voltage had dropped from 46.5 to 45 volts. Further runs were,

Volts, 53.5. Ampères, 14.5. Auxiliary current—Ampères, 6.2.

The run lasted half an hour and stopped only on account of the failure of the pump belonging to the break (see below). In this time the voltage had gone up one volt, and the ampères one-half ampère.

Volts, 69. Ampères, 19.4. Auxiliary current—Ampères, 6.

Run of fifteen minutes. Oscillation very slight, even with variation of two volts and a quarter and one-quarter ampère in the supply.

Volts, 97. Ampères, 12.5. Auxiliary current—Ampères, 4.25.

When the synchronism failed it was on account of the large change in load caused by slipping of the driving belt.

It is thus evident that the method is a practical one up to more than one and a half horse-power. This is more than would be needed in by far the greater number of its obvious applications. The method seems to me of undoubted usefulness in absolute determinations, and may be useful in connection with the driving of telescopes. It is difficult to get exact statements as to the accuracy of existing governors, so that I am unable to state whether the method here given is sufficiently accurate or not. It has been used in the laboratory of Clark University for a number of purposes, one of which is described by Mr. C. A. Saunders in an article in the *Physical Review*, Sept.-Oct., 1896. By the same means a siren is converted into an instrument of precision, far superior to apparatus costing much more. A chronograph for astronomical purposes has been constructed on the same principle, whose performance will be described elsewhere.

ART. XXXVI.—*A Rapid Break for large Currents*; by
A. G. WEBSTER, PH.D.

THE necessity frequently arises of breaking a current of a number of ampères with regularity and considerable rapidity, particularly in connection with induction coils, as in the experiments of Hertz, Tesla, and recently of Röntgen. The breaks usually furnished with induction coils are useless for much more than five ampères, and are at best slow and irregular. Mercury breaks are usually very disagreeable to work with and soon become useless from oxidation. Perhaps as simple and satisfactory a break as any is a revolving slate disc with metallic sectors, as used by Wadsworth, Pupin, and others, with, if necessary, an arrangement for blowing out the spark. Such breaks, however, usually burn up in time. If a very regular break is necessary, however, this device is not applicable, and one naturally has recourse to a tuning-fork. Such a necessity presented itself to the writer when he attempted to regulate the speed of an electric motor as described in the preceding article. With a tuning-fork a mercury break becomes a necessity, as anything else would produce too great a disturbance in the period of the fork. In order to prevent burning up the mercury the contact must take place under some fluid. Water is dirty, alcohol takes fire, and other liquids generally produce a great amount of refuse in a short time. It is therefore necessary to keep a current of liquid flowing over the mercury. After trying a stream of water for some time, and finding that the mercury gradually disappeared from oxidation, and that the platinum wire was also consumed, the writer was laying the matter aside when he was informed by Professor Wadsworth, of the University of Chicago, that a stream of mercury from a jet was used in the laboratory there, for currents of one or two ampères, the idea having been suggested, I believe, by Professor Stratton of that university. A jet of water had been previously used by Bedell and Crehore. It occurred to the writer that if the break were made under water, and the mercury were continuously elevated, that this would furnish the desired break.

The first thing that suggested itself as a means of elevating the mercury was an application of the ingenious device described by Dr. Pupin, in connection with a Sprengel air-pump (this Journal, January, 1895). A short experience with a vertical mercury-jet surrounded by a stream of water showed that this arrangement would not answer, on account of spattering of both water and mercury. The arrangement finally

adopted is shown in fig. 1, the elevator being on the left. An aspirating water-pump is connected to the tube C, at the end

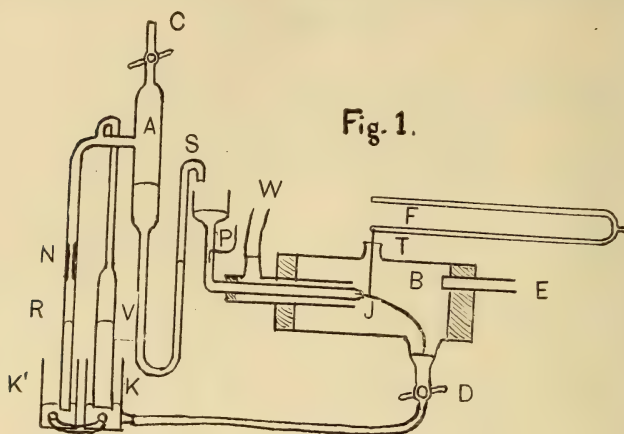


Fig. 1.

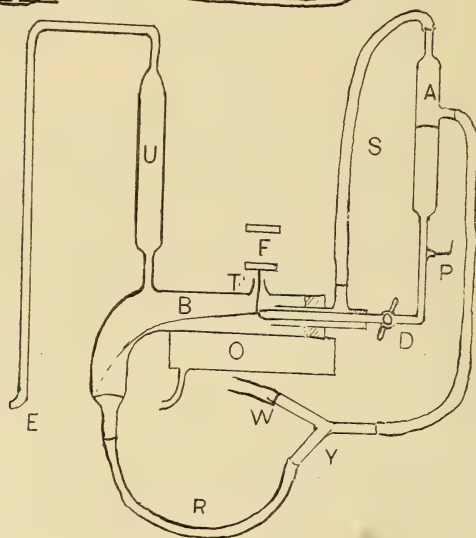


Fig. 2.

of the supply-tube A, which contains mercury at the start. On account of the vacuum, the mercury to be elevated, contained in the cups K and K', which are connected by a small rubber tube, rises in the tubes R and V, while the mercury in the discharge tube S descends. Owing to the large size of the tube V, the level in K descends rapidly, followed by that in K', so that the end of the tube R is exposed to the air, which raises the column of mercury in R. When the column passes the con-

striction N, it is suddenly jerked up over into A, the level in S rises, and the quantity corresponding to that which has been raised runs over into the funnel. The mercury in V has in the mean time run down into K, and the process is repeated. The mercury in the funnel runs down through the jet J, through the tube B full of water, runs out at the bottom through the cock D, and through a rubber tube descends to the cup K. The current is introduced by a platinum wire sealed into the glass at P, and goes out at the wire carried by the fork F, and dipping into the mercury through the short standing-tube T. Water is introduced at W around the jet, and flows out at E. The tube is kept full of water, so that the jet is kept cool; the jet presents a continually fresh surface of mercury, the mercury is washed in the flowing water, and comes out perfectly clean. The oxide goes off in the waste water at E. The surface of the mercury is kept just below the tube B, so that no water goes over into the elevator. The cock D is for the purpose of keeping the mercury from all running down into the cups K on stopping the action of the apparatus, and C is to prevent water from the pump getting into A on stopping the aspirator.

The apparatus thus described was very satisfactory, a test made of its automatic nature having shown that a current of twelve mean ampères was carried for an hour without any adjustment of the apparatus. For longer periods it would be necessary to occasionally pour in a little mercury to replace that lost by oxidation, much of which may be recovered by running the waste water through a pail in which it may settle. The above arrangement seeming rather unnecessarily complicated, it occurred to me to try to raise the mercury directly by water instead of air pressure. To this end a jet of water was introduced into a tube containing the mercury to be raised, somewhat in the manner of the Giffard injector. This was successful, but the mercury was carried up in a multitude of fine globules, which sometimes made the stream discontinuous. The arrangement was finally simplified by my assistant, Mr. A. P. Wills, into a simple Y-tube, and the apparatus as now used is shown in fig. 2. The water is introduced at W into one arm of the tube Y, into which the mercury enters through the other branch from R. The mercury is carried to the right and upwards, and is thrown into the supply tube A in quantities of about a tea-spoonful at a time. The water escapes at the top of A and descending through the rubber tube S enters around the jet and keeps the break cool. The waste water rises through the wide tube U, so that any mercury that might be carried over settles and falls back. The water escapes through the siphon E, which should have a pinch-cock at the end to

prevent air being sucked in at T on stopping the action. The cock D is also to be closed at the same time. O is a trough to catch any water that may overflow at T. The flow should be adjusted so that water is just about to overflow at T; the spark is then well under water, and no air is likely to be drawn into the water tube P. The tube R must have length enough to hang down with a certain amount of slack, so that the mercury shall have inertia enough for the proper working of the pump. When the proper arrangement is arrived at, the level of the mercury fluctuates with a regular pulsating motion, and at each pulsation the water is momentarily shut off in Y and mercury is carried up. In order to start the apparatus working it is only necessary to turn on the water and open the cock D. The apparatus of the size indicated in the figure working on a head of two and one-half meters of water with a flow of about three-tenths of a gallon per minute, has carried a current of twenty ampères, and has been used with forks giving fifty and one hundred breaks per second. I know of no other arrangement which will stand such a current for any length of time.

Clark University, Worcester, Mass.

ART. XXXVII.—*The Electrical Conductivity of the Ether* ;
by JOHN TROWBRIDGE.

I STATED in the April number of this Journal that my experiments have led me to the conclusion that the chief resistance in overcoming the apparent resistance of a highly rarified medium is encountered at the surface of the electrodes (*ueber gangschicht*) and that when this is overcome the ether offers little resistance. The method I have employed seems to me to be a very useful one for the study of electrical discharges. It may be termed the damping of the additional spark method, or the comparison of resistances by the estimation of the damping of electrical oscillations.* The electrical circuit is provided with two spark gaps. One of these is placed in a gas, or under the conditions which are to be examined, while the other is photographed according to Feddersen's method by a revolving mirror. With cadmium terminals this method enables one to estimate the resistance of a spark in air or in rarified media to one-half an ohm.

Having at my command a battery giving a voltage of twenty thousand, with an internal resistance of only one-quarter of an ohm per cell, and capable therefore of giving a very powerful current, I first studied the behavior of Crookes tubes which were connected to the terminals of this battery. I found that no Röntgen rays could be obtained with a voltage of twenty thousand. On heating the Crookes tubes, they were filled with a pale white light, which showed very faint bands in the green when examined by the spectroscope. Then the entire strength of the battery appeared to be manifested in the tubes, the electrodes became red hot—the medium broke down and offered no resistance to the current of the battery. This white discharge showed even at its culminating point no Röntgen rays. I then employed the Planté rheostatic machine. This apparatus, I think, has not received sufficient attention from physicists. In connection with a large battery, it is very efficient, and it enables one to form an estimate of the high electromotive force that one employs in the study of the Röntgen rays. I have slightly modified the form of the machine as it is given by Planté. The main principle consists in discharging Leyden jars in multiple and then discharging them in series. The proportion of the length of spark to the number of jars is very close. Knowing the electromotive force of the battery which charges the jars, we can estimate the voltage necessary to produce sparks of different lengths. I

* Damping of Electrical Oscillations on iron wires, *Phil. Mag.*, Dec., 1891. Also *American Journal of Science*, April, 1897.

speedily found that at least one hundred thousand volts were necessary to produce the Röntgen rays and they were produced more intensely as I increased the voltage, certainly to the point of five hundred thousand volts.

In order to ascertain whether the discharges through the Crookes tubes when the Röntgen rays were apparently produced most strongly were oscillatory, I first placed a Geissler tube in the circuit with the Crookes tube and carefully observed the appearance of the two electrodes of the Geissler tube. They were quite alike and indicated an oscillatory discharge. I then replaced the latter tube by a small spark gap and photographed it in a rapidly revolving mirror. The photograph showed at least ten oscillations with a period of about one ten-millionth of a second with the Crookes tube and the circuit I employed. Furthermore, applying the method of estimating resistances by the method of damping, I found that the resistance of the rarified medium was less than five ohms. The energy, therefore, at the moment of the emission of the Röntgen rays, was not far from three million horse power, acting for one millionth of a second. I employed also a Crookes tube with an aluminum mirror of about two centimeters focus. The resistance of this tube to the discharge was the same as that in which the mirror had a focal length of six centimeters. Incidentally, there seems to be no advantage in shortening the distance between the cathode and the anode—by employing a mirror of short focus. Struck by the fact that the distance between the electrodes did not appear to make any appreciable difference in the resistance of the Crookes tube, I replaced the latter by a spark gap of six inches in length in air, and photographed the spark in another gap in air in the same circuit. This latter gap was one-quarter of an inch. The photographs showed on an average the same number of oscillations whether the additional spark gap was six inches in length or one inch in length. I found, moreover, that on increasing the electromotive force the resistance of the sparks in air decreased. By quickly drawing apart the terminals of my large battery I can produce a flaming discharge in air of about three feet in length. Rhigi has also observed the same phenomenon with sparks from an electrical machine. We see that no increase in resistance results. I then placed the secondary spark gap in a receiver and studied the resistance offered by rarified air at the point when long ribbon light white disruptive discharges can be obtained. This point is at about 100^{cm} pressure. The resistance of such discharges of about six inches in length in a receiver containing air at this pressure is two or three ohms more than sparks of one quarter of an inch in air, which have a resistance of from 2 to 3 ohms. On measuring by the above

method the resistance of sparks of different lengths in the receiver at this pressure, no difference in resistance could be perceived between a spark of six inches in length and one of three inches in length.

The secondary spark gap was next placed in a chamber of air which was compressed to four atmospheres. This amount of compression made no difference in the resistance to the disruptive discharges. The secondary spark was also obtained in hydrogen gas generated by electrolysis at atmospheric pressure, and no appreciable difference in resistance between this gas and air was noticed. The length of spark which could be obtained with a given voltage was somewhat more in hydrogen than in air. It was interesting, in the next place, to determine by this method whether differences in the material of the spark gaps made any difference in the resistances observed in the case of disruptive discharges.* I accordingly employed terminals of platinum, iron, aluminum, brass, cadmium, and zinc, and could perceive no difference. Moreover, any difference of resistance between spheres and between pointed terminals, or between a point and a plane, seemed to be inappreciable. With powerful discharges such differences, if they exist, apparently disappear. The secondary spark was next placed in a heated flame. It is well known that the spark length can be thus greatly increased. On photographing a spark in an additional gap, the resistance appeared to be slightly increased in the flame; doubling the length of this spark however, made no change in the resistance that was encountered in the heated medium. The phenomenon was exactly analogous to that observed in the receiver exhausted to 100^{cm}. I was interested to observe whether heating the spark in the primary of a Thomson Tesla transformer produced any marked change in the high tension spark of its secondary. It was evident that it was detrimental. The high tension sparks immediately ceased to jump at the extreme sparking distance of the terminals. Following this train of thought, I next placed a spark gap of the primary of the above mentioned transformer between the poles of a very powerful magnet, giving a field of certainly ten thousand lines to the centimeter. It is well known that when such a field is excited, the primary spark appears to be blown out with a loud report and a great increase of length of spark is obtained in the secondary of the transformer. Applying the same method, I photographed the spark of the additional spark gap and found no difference in resistance whether the magnetic field was excited or not: or when the spark jumped across the magnetic lines or in the

* Rhigi ovo Cimento (2), 16, p. 97, 1876; De la Rue and Hugo Muller, *Phil. Trans.*, 169, Pt. 1, p. 93, 1878.

direction of the latter. Is it possible that, the ether being already under a magnetic stress, the addition of a powerful electrostatic stress serves to suddenly break down the ether? It is well known that a blast of air imitates the action of the magnetic field. It probably does so by blowing out the voltaic arc which tends to form. It may be that the electrodynamic repulsion compels the spark not to follow, so to speak, the voltaic arc and its current of heated air. The loud report may indicate a sudden stress in the medium, and in the case of the Crookes tube the highly rarified medium within it would effectually prevent our hearing a similar report.

I next placed the primary spark of the Thomson Tesla transformer near a Crookes tube which was giving out the Röntgen rays. I could not perceive any mutual effect. The effect, moreover, of ultra violet light on the resistance of sparks in air could not be detected.

The method I have outlined enables one to form an estimate of the energy incident upon the production of the Röntgen rays. It can also measure with greater accuracy the resistance of sparks in air and different media. It shows conclusively that the discharge in a Crookes tube at the instant when the Röntgen rays are being emitted most intensely, is an oscillatory discharge. In popular language it can be maintained that a discharge of lightning a mile long under certain conditions encounters no more resistance during its oscillations than one of a foot in length. In other words Ohm's law does not hold for electric sparks in air or gases. Disruptive discharges in gases and in air appear to be of the nature of voltaic arcs. Each oscillation can be considered as forming an arc. It is well known that a minute spark precedes the formation of the voltaic arc in air. The medium is first broken down and then the arc follows. I believe that this process occurs also in a vacuum and that absolute contact is not necessary to start the arc. My experiments lead me to conclude that under very high electrical stress the ether breaks down and becomes a good conductor.

Jefferson Physical Laboratory, Harvard University.

ART. XXXVIII.—*The Effect of Great Current Strength on the Conductivity of Electrolytes*; by THEODORE WILLIAM RICHARDS and JOHN TROWBRIDGE.

IN a recent paper on the temperature and ohmic resistance of gases during the oscillatory electric discharge,* we have described a method of determining resistance by measuring its damping effect upon electric oscillations. The method is obviously one which will apply to electrolytes also, provided that the resistance to be measured is less than twenty ohms; and it seemed to be very well worth while to determine if the intense current involved in the discharge of a large condenser is capable of causing any change in the condition of an electrolyte.

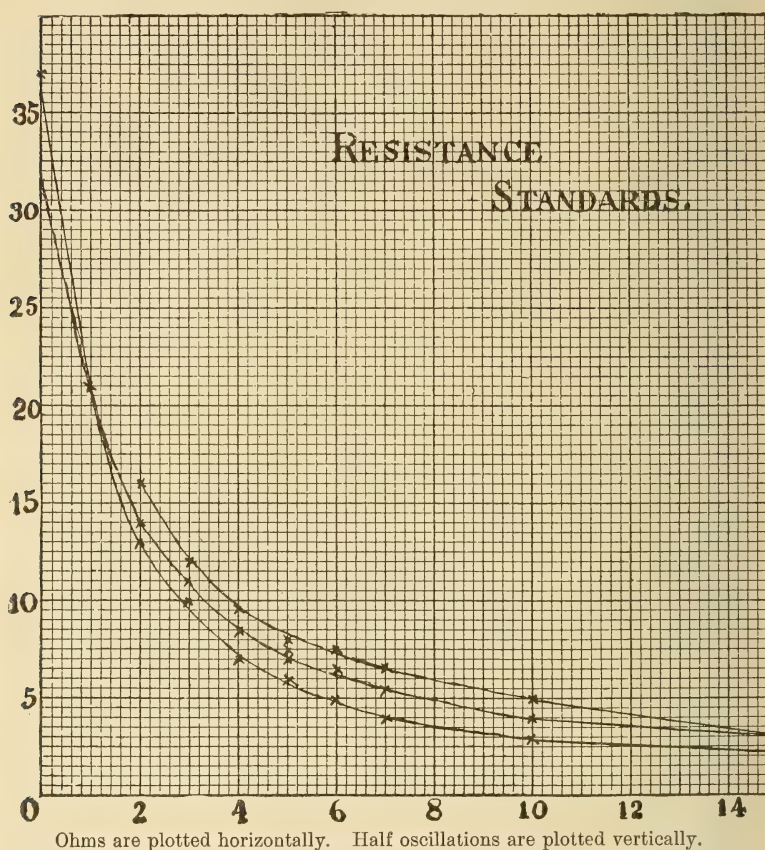
In our first experiment, two copper plates of sixteen square centimeters area were clamped at a distance of three centimeters apart by means of vulcanite. Upon being immersed in a saturated solution of pure cupric sulphate at 15° C, the plates allowed about ten oscillations from one of our large Leyden jars, nine from two jars, and eight from three jars, to pass through it. According to the scale of standards, reprinted from our last paper,* each of these results corresponds to a little less than four ohms resistance. By means of Kohlrausch's method, using a very small inductorium, this cell gave an extremely poor minimum at a point corresponding to a resistance of about ten ohms. The plates, which had purposely been left very dirty, in order to test the efficiency of the method, were now scrupulously cleaned with alkali and acid, and were then both carefully plated with pure copper. With Kohlrausch's method, the cell now gave an excellent minimum at exactly four ohms resistance, and further cleaning and plating caused no further change. New photographs of the sparks from the two jars sent through the cell showed again about nine half oscillations, corresponding to about 3.8 ohms. It is evident, then, that the resistance of concentrated cupric sulphate is not essentially altered by great alterations in the strength of the current.

Experiments with zincic sulphate gave similar results, and a solution of cadmic sulphate between cadmium electrodes which possessed a resistance of 4.7 ohms according to Kohlrausch's method, gave nine, seven, and six half oscillations with one, two, and three jars respectively, corresponding to about 5 ohms in each case.

Undoubtedly the reason why the strong instantaneous current, which alters so much the resistance of gases, has so little effect upon solutions, is because of the great mass and specific

* This Journal, vol. iii, p. 327.

heat of the material which must be warmed in the latter case. The average temperature of the solution rose during our experiments only at a rate of about 1° in three minutes.



A similar, although smaller, heat capacity prevents the wire resistances which are used as standards from becoming seriously altered in resistance by the heat. We had used manganin wire in our tests, but in order to be sure that our fine short wires had not been overheated, we constructed a five-ohm resistance of four strands of coarser manganin wire about 0.25 mm diameter and 3.5 meters long. This was stretched upon each side of a thin vulcanite plate to avoid self-induction, but it allowed essentially the same number of oscillations to pass as did the short fine wire. A short German-silver wire, with a very high temperature-coefficient, showed a conductivity only a very little

less; thus the error from the heating of the wire may be neglected.

In order to show that common electrolytic polarization does not interfere with the accuracy of our method, we measured with the help of our 20,000 volt storage battery and condensers the resistance between two bright platinum plates similar in size to the copper ones used before, in a cupric sulphate solution. This was found to be four ohms; and after plating the electrodes with copper the resistance remained unchanged. Kohlrausch's method gave no satisfactory result with both electrodes free from copper; but when both were plated it indicated a resistance of 3.9 ohms.

Our method may therefore be a useful one for the approximate determination of conductivities in cases where impurities or polarization render Kohlrausch's method unsatisfactory. For accuracy, of course, pains must be taken to develop all the photographs in the same fashion, and in general to arrange the conditions of the exposure alike in all cases.

Our conclusion, that the conductivity of electrolytes is not essentially affected by great changes in current strength, only emphasizes all the more strongly the conclusion of our last paper, that the conductivity of gases is very much affected by changes in the current strength.

Harvard University, March 8, 1897.

ART. XXXIX.—*On the Southern Devonian formations*; by
HENRY S. WILLIAMS.

[Read before the Geological Society of America, Dec. 31st, 1896.]

ONE of the most remarkable contrasts of geological correlation is met with on passing from the Devonian system, as it is typically expressed in New York state, to the expression of the same system as found in Tennessee and Alabama.

In the north, following the Silurian formations in regular sequence, there is a series of varying sediments, reaching several thousand feet in thickness, made up of numerous separate formations, sharply differing in the kind of materials composing them and containing well-differentiated faunas. In the south a uniform black shale, with perfectly even sedimentation, the grain of the rock presenting almost no difference from top to bottom, containing a meagre fauna and evidence of a common plant vegetation so long and so far as it may be distributed in its purity, and varying in thickness from 500 to 900 feet in some sections to a few inches in thickness in some of the Alabama sections, and often resting unconformably upon Niagara,

Trenton or even lower rocks. The remarkable nature of this contrast is emphasized by the fact that the two extremes are both within a common intercontinental basin.

In order to understand the nature of the problem it is essential to consider the geographical conditions which prevailed during the Devonian era in this eastern part of North America. Referring to the chart on the opposite page, it will be observed that the main part of the eastern half of the continent south of the great lakes and west of the ridge of the Appalachians was a Mediterranean sea. The northern shore extended from Minnesota to eastern New York. The land to the north (L), which was chiefly Archæan, may be called Laurentia. On the east (A) was a shore line extending from eastern New York to central Alabama, the land of which may be called Appalachia. Indications in Arkansas, Indian territory and Texas point to land surfaces along the gulf-border states (K, T), but their exact extent, and whether islands or continuous shores on the southern border of the sea, is uncertain. From the north a wide open oceanic channel swept from the Mackenzie river valley region across British America, the Dakotas, Nebraska, and Kansas far into and through the western Texas region to the south. This channel was bounded on the west by the extensive Archæan islands or edges of lands constituting the eastern axis of the present Rocky Mountains (R), and it may be called the Dakota channel.

From the northern shore of the interior continental sea, over what is now Wisconsin, a peninsula (W), extended southward in the early part and, perhaps, the closing part of Devonian time, which may have constituted shallows as far as the Missouri island (M). This Missouri island occupied considerable of the southeastern part of Missouri, made to be of greater or lesser extent with the oscillations of level which occurred during the Devonian era. In the midst of the intercontinental sea thus constituted there was a low ridge (C), sometimes land, sometimes partly land and partly shallow ridge, under tide level, which extended more or less continuously from western Ontario to central Alabama; this may be called the Cincinnati plateau. The rocks forming the surface of this plateau were, chiefly, Ordovician limestones, while the shores of Appalachia and Laurentia were chiefly of Archæan rocks.

In studying the Devonian system of this interior continental area most of the differences in stratigraphy, met with along the northern border and the northern part of the Appalachian shore, are readily interpreted by the application of two general geological principles. These are the following: (1) the differences between limestones on the one hand and clastic rocks, composed of fragments of argillaceous, arenaceous or conglomerate nature, are accounted for by the different origins of the

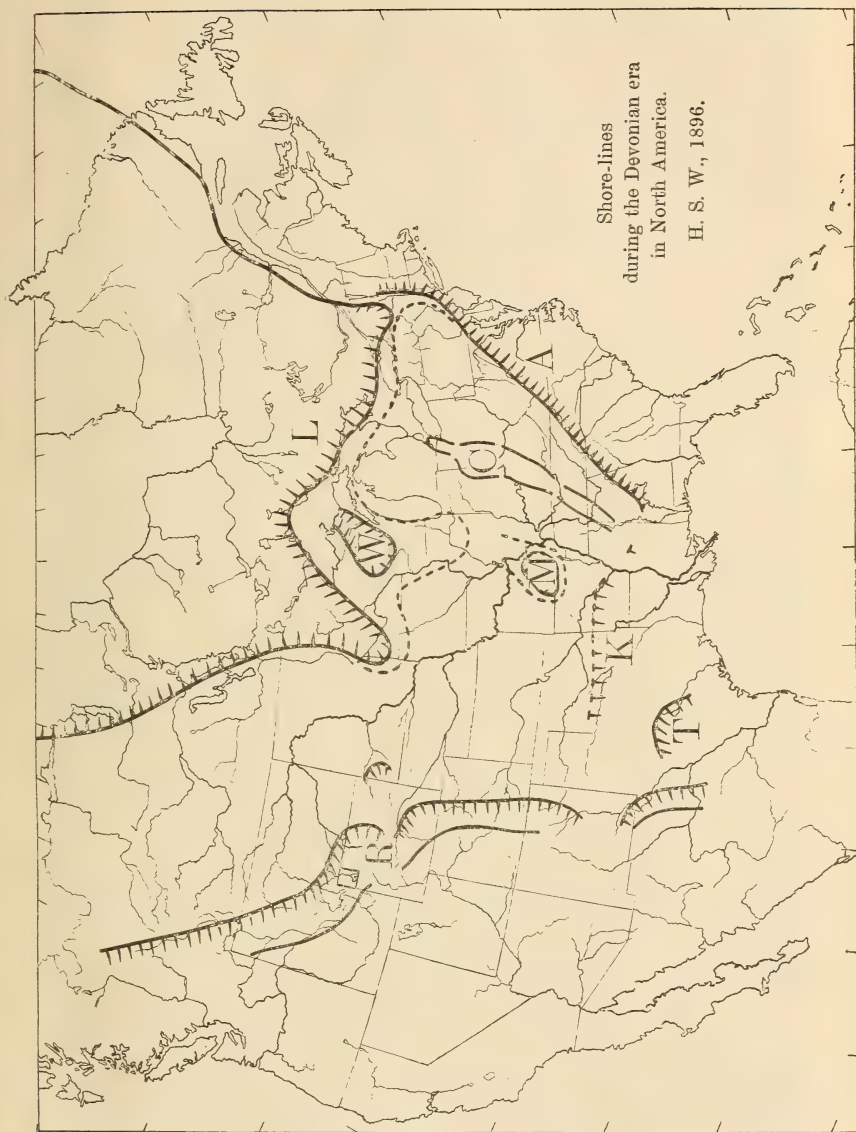


Chart showing the approximate position of the Devonian intercontinental sea. The strong lines with fringes represent the edges of undoubted land masses of Silurian time; the dotted lines probable extension of these shores during Devonian time; heavy line about O = oscillating shore lines of which the exact margin is unknown; L, Laurentia land; A, Appalachia land; R, Rocky Mountain lands or islands; W, Wisconsin peninsula; C, Cincinnati plateau; M, Missouri island; K, probable edge of a land-mass over Arkansas and Indian territory; T, a piece of shore-line in Texas, the extension of which is unknown.

materials themselves; i. e. limestone, carbonaceous and phosphatic materials are of organic origin, while clastic sediments are derived from the decay, fracture and grinding up of pre-existing, generally, crystalline and, therefore chiefly, Archæan rocks. (2) The differences in size or fineness of grain of the materials of clastic rocks may be accounted for by the sorting action of moving waters; and thus all the varieties of rocks are brought into a general relationship to the distance from the shore-line off which they were finally deposited. By the application of these general principles it was found possible to interpret the geographical changes in the stratigraphy of the formations across New York state, northern Pennsylvania and Ohio in terms of distance from the shore line and of oscillations of that line backward and forward with general vertical movements of the crust. By these principles the Catskill was shown to be, not a definite chronological formation representing the time following the period of the Chemung fauna, but an along-shore facies of the Devonian deposits of the northeastern bay of this interior sea incident to a gradual rising of the lands at that part of the region. The sediments of Catskill facies, therefore, occurred as early as the Hamilton in eastern New York, while they did not occupy the area of western New York till after the end of the Chemung period.*

The entrance of the Cuboides fauna into the New York area east of the Cincinnati plateau was also thus found to be coincident with the changes of level which were recorded in central-western New York and Pennsylvania, by the presence of a local limestone of the Tully epoch; this depression giving access to the faunas which had already, in Hamilton time, reached as far south as Iowa from the Dakota channel at the north.† While the two general principles named were sufficient to account for these and other differences, I have been unable by any combination or commutation of these alone to arrive at a satisfactory explanation of the Black shales, so conspicuous to the south, or of the Oriskany whose center of distribution seems to be far up in the northeast corner of the sea.

On the supposition that the black shales were clastic sediments, derived from the same sources with the other clastic sediments of the Devonian system, they should appear in the sections, all around the shores of Laurentia and Appalachia, wherever the corresponding fineness of division was reached; but this does not agree with the facts, for in the southern sections black shale sedimentation prevails throughout the whole

* Dual nomenclature in geological classification. Jour. Geol., vol. ii, pp. 145-160, 1894.

† The Cuboides zone and its fauna, Geol. Soc. Am. Bull., vol. i, pp. 481-500. The scope of Paleontology and its value to geologists, Proc. A. A. A. S., vol. xli, pp. 149-170, 1893.

period of the accumulation of these varying sediments, including some sheets of black shale, as well as several belts of equally fine sediments which do not carry the black shale fauna. Also the geographical distribution of the black shales is not at all related to distance from these shores. Hence it has been necessary to give to the geologist, who has appealed to the paleontologist to know what is the age of the southern black shale, the same kind of answer Lonsdale gave regarding the original rocks of Devonshire, that all we know is that they are younger than Silurian and older than the central member of the Mississippian series of the interior. In like manner the sudden appearance of the coarse and quite uniform sands of the Oriskany epoch, in the northeastern corner of the interior continental sea, following immediately after the Helderberg, which was a limestone with its center of distribution also there, finds no solution upon the theory of rise of the shore, especially when we consider that its distribution is limited to the shores of the Laurentia and Appalachia lands and possibly some parts of the Cincinnati plateau. Some other factors than those usually applied to the solution of correlation problems must be brought under consideration. It is necessary to explain the general conditions of sedimentation for the whole basin in Devonian time, and also the reasons for the differences of sedimentation in different parts of the area. It is also necessary to explain the almost total absence of a series of varied faunas, abundant in the northern and northeastern part of the basin, from the southern central part. To reach these ends a minute study of the relations of the black shale to the sediments and conditions both preceding and following its occurrence, in purity, seemed likely to throw some light. The studies already made in Arkansas and Tennessee seemed to warrant the conclusion that in certain sections of the south there was unconformity below the black shale, and the suspicion was forced upon my mind that the base of the shales themselves was of varying age. The suggestion made in Mr. Hayes' paper on the Tennessee phosphates,* that the bottom might have been scoured by ocean currents, led me to think that ocean currents might account for the distribution of the black muds.

In order to study the facts more minutely I spent several weeks last summer in southern Virginia, Tennessee and Kentucky. The Estillville sheet† of southern Virginia prepared by Mr. Campbell offered the most promising field for ascertaining the relationship of the black mud sediments to other elastic

* The Tennessee Phosphates, by Charles W. Hayes, 17th Ann. Rept. U. S. Geol. Survey, Part IV, pp 610-630, 1895.

† Estillville Folio, Ky. Va. and Tenn. U. S. G. S. Geol., by M. R. Campbell, 1894. "Geology of the Big Stone Gap Coal field of Va. and Ky.," by M. R. Campbell. Bull. No. 111, U. S. G. S., 1893.

types, because of the great thickness of the black "Chattanooga shales" at Big Stone Gap and the great thickness of the following "Grainger shales" which were called Devonian, though with some hesitation, as Mr. Campbell stated, on account of lack of fossils. An examination of the black shale at Big Stone Gap, which is at least 500 feet thick, revealed not the least addition to the meagre *Lingula* fauna, but made clear that the following arenaceous shales and sandstones began as very thin intercalated sheets, thin as paper at first, far down in what, to the casual observer, appeared to be pure black shale. This led to the expectation that the section farther east (i. e. nearer to the ancient shore line) would show the shore-derived sediments earlier in the section. This expectation was confirmed by following the section eastward to Moccasin Gap, where in the arenaceous shales well above the pure black shale, in what was mapped as Grainger shale, a distinct Carboniferous fauna (the *Syringothyris* fauna of the Kinderhook age) was discovered. These observations confirmed the belief that the black shale material was derived from a different direction from the other clastic sediments making up the section.

Examination of the sections at Irvine, Kentucky, the other side of the Cumberland channel (the name which may be given to the southern part of the Devonian intercontinental sea lying between the Cincinnati plateau and Appalachia) revealed the fact that there the black shales were thinner but held on in their purity well up into Carboniferous time. The intercalations consist of calcareous and ferruginous, concretionary sheets and carry undoubted Carboniferous fossils and occur in the sections before the black shale loses its characteristic expression. This settled the suspicion that the black shale materials were derived from the direction of the Cincinnati plateau and not from the Appalachia side of the channel, since on the plateau side of the channel they were pure and continued later in the section, and on the Appalachia side, where there were other clastic sediments following, these sediments from the Archæan land-wash increased and were found lower down in the section on approaching the land edge.

Thus the conclusion was reached that the Cincinnati plateau was the source of the black shale muds, and to account for their distribution the agency of an ocean current, such as the Florida current of the Gulf stream is at present in the Atlantic, was introduced.

The next question arising was as to the age of the base of the black shale. The study of the Big Stone Gap sections also threw light on this problem. On the Kentucky side of the Cumberland channel, as well as on the Appalachia side, there are frequently represented at the base of the black shales beds of brown iron ore. About Big Stone Gap this brown ore con-

tains corals which appear to be of Corniferous age, and below is a sandstone capping the Helderberg limestone. At a single locality, under the woollen mill on the bank of the east branch of Powell river east of Big Stone Gap, in the place of the ore the limestone is quite filled with corals in place, followed immediately by the black shales with no intervening iron ore. This seems to fix the date of the beginning of the black shales for this region at an horizon closely corresponding to that of the Marcellus shale in the New York section.

Hence it may be safe to conclude that in Tennessee, Alabama, southern Kentucky and probably Arkansas, whenever the black shales rest on some formation lower than the Lower Helderberg limestone (for the absence of Oriskany will be explained in another way beyond) that either there had been elevation and therefore no sedimentation, or that the rocks had been eroded away before the black shales were laid down. The erosion may have been partly done under water, by the scouring action of a strong ocean current washing in from the west between the Missouri island and the land areas in southern Arkansas (between M and K, see chart). The fact of the interval containing the black shale over much of this region, an interval reaching, often, to the Ordovician and even lower, together with the presence of a low anticlinal of the Cincinnati plateau extending farther north, suggests the probability of land surface more or less continuously connecting the southern end of Appalachia with the Texas area.*

An examination of the chart will at once make evident that in case there was, as we should expect, an ocean current flowing southward through the Dakota channel, the effect of raising the bottom above tide level along the gulf border states (along T and K), would be the deflecting of the current with a powerful swirl into the southern part of the interior continental basin. Even if the elevation were only to make a string of islands in this region, a part of the current would enter the basin and wash across the northern Arkansas, Tennessee, Alabama surfaces, and would tend to move the bulk of the muds of the bottom into the Cumberland channel and thence northward. As a working hypothesis, this is supposed to have taken place; and what we know of the general distribution of the black shales is consistent with such an hypothesis.

The presence of polished sand grains, with nodules of black shale mud, and rolled and polished fragments of large fish bones, some of them from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in thickness, associated with more or less phosphate of lime, at the bottom of the shales, over the southern extension of the Cincinnati

*In the discussion which followed the reading of this paper Mr. Hayes informed us that the black shale thickens in central Alabama, thus confirming the probability of land in that direction during Devonian time.

plateau, and also along the southern shores of the Missouri island, is further in harmony with the hypothesis of current-scour and transportation. Since the black shale conditions followed soon after the first appearance of the Oriskany sediments and fauna in the basin, this event requires consideration.

The more conspicuous facts regarding the Oriskany crisis are the following: In a great interior continental basin, closed all around its north, east and part of its southern border (see the chart), the closing epoch of the Silurian era was marked by a widely distributed limestone accumulation which appears to have its purer and more characteristic center in the extreme northeastern part of the basin. Here depression was taking place so that in eastern New York the formation is markedly thicker than in its western part. Suddenly there was an irruption of coarse sand with a sharply differentiated fauna, which from Oriskany Falls, N. Y., extends in diminishing thickness across to Ontario, Canada. On the eastern shore, however, along the edge of Appalachia, as far as Georgia, the fauna at its base appears to be more or less blended with the Helderberg species which continue upward in the sections. In the extreme southward extension only a few of the Oriskany species reach the region and the Helderberg fauna does not appear to cease till after the Oriskany conditions of sedimentation had closed. In eastern Pennsylvania, the coarser Oriskany sediments are not found on the extreme eastern side but as far west as the Lehigh Water Gap, where, too, they are thicker, by four times, than at the Delaware Water Gap, some thirty miles further east, and the more eastern sections are limestones and lime shales, while to the westward sandstones and conglomerates appear in heavy sections.*

Furthermore, when we examine the distribution of the fauna we discover that, while it constitutes the principal Devonian marine fauna in the troughs entering from the east into the Acadian and New England region, both the sedimentation and fauna of the Oriskany of the interior continental basin are confined to the shores of Laurentia and Appalachia east of the Cincinnati plateau, and to the eastern shore of the Cincinnati plateau. In its purity the fauna is confined to the northeast bay of this interior continental sea. To explain all these peculiar conditions one event seems to be fully sufficient. If we suppose that the sinking of the area, including the northeastern rim of this basin, continued till sea level was reached, we then have a sufficient cause for the incursion of the vast amount of coarse sands, and with them the new fauna, which suddenly appeared first in the extreme northeast corner of this inland sea. There is sufficient reason for the belief that such a sinking was going on during Helderberg time, and that it extends along the Champlain valley as far as Montreal, near

* See Penn. Geol. Surv. Summary, final report, vol. ii, p. 1042.

which on the island of St. Helena a small patch of Helderberg limestone is still preserved, and still further on to connect with the eastern ocean across the St. Lawrence Valley.

Such a depression is also the natural correlative of the elevation at the southwestern corner of the basin which the various facts already in hand seem to call for. It is not difficult to imagine an event similar to this as possible at the present epoch, by which a slight depression, taking below sea-level the shores of northern Europe, would let in the cold waters of the north to spread over the plains of Russia, into the Black Sea and through to the Mediterranean, changing its fauna, and, if the current were strong enough, covering the bottom with the wash of the land, and with a rapidity, and in quantities, far in excess of the sedimentation ordinarily occurring there. The catastrophic effects would be coördinate with the reaching of a culmination point in slowly and regularly operating movements of the crust. The crisis would occur when the sea level was reached in the slow depression of the northern continental rim. Such an event is supposed to have occurred at the time of the incursion of the great mass of elastic sediments into the Lower Helderberg sea with a new fauna which marked the opening of the Oriskany epoch in North America.

In the hypothesis here offered to explain the differences in stratigraphy presented by the formations of the Devonian in various points of the intercontinental basin of eastern North America, a few fundamental principles are introduced which have heretofore been entirely ignored, or given a very insignificant place in the solution of such problems.

1st. *A two-fold source for the elastic sediments forming the material of the strata of a common section.*—In the present case the black shale sediments are supposed to have been derived from the decay of Lower Silurian rocks protruding more or less above sea-level along the Cincinnati plateau, and not from the surfaces of the Laurentia or Appalachia lands, from which the sediments making up the bulk of the strata bordering these lands seaward were derived.

2d. *The agency of ocean currents in determining the geographical distribution of sediments not derived from the immediate coasts along which they were deposited.*—In the cases of the black shale and of the Oriskany sediments this agency explains conditions of distribution which have not been accounted for by any cause heretofore suggested, so far as I am aware. And the reconstruction of the topographical conditions of the region from facts already known is not inconsistent with the assumption that the required currents actually existed in the basin during the time when the distribution of the sediments took place.

3d. *The catastrophic effects, upon the sedimentation, and upon the inhabitants of a more or less inclosed marine basin, produced by the passing below tide level of a portion of the rim of such a basin.*—In the case of the Oriskany the opening of such a passage from the interior basin to the northeastward, will account for the sudden wash of a great mass of indiscriminate sediments, from the tide-swept, depressed land into the basin during the depression which was marked before and after by limestone-accumulations throughout the northeast bay. This will explain the purity of the Oriskany fauna and sediments only in the northeast corner of the basin, and their entire absence along the western extension of the great basin, from which direction, in the absence of such a depression, we should have expected them to arrive into the waters of the basin.

In addition to these three geological principles there are a few biological principles which have been adopted as working hypotheses, the formulation of which may be appropriate in this connection.

A. It is assumed that in a common intercontinental marine basin, such as evidently existed during Devonian time over this region, the various faunas living in the basin, after having attained a biological equilibrium to their conditions of environment and to each other, will preserve their integrity so long as the conditions of environment remain constant.

B. The passage from one formation to another, involving a change of fauna, is, therefore, assumed to indicate a change in the conditions of environment. This change is usually expressed in terms of difference in the character of the sediments.

C. These changes in the conditions of environment may be of two kinds. One of them consists in oscillations of level, gradually shifting the shore conditions, but consistent with a movement of the species to adjust themselves to the slightly changing conditions. In this way the local differences of a common general fauna may be explained. In this case it is probable that the faunas would not acquire any new genera not already living in the basin, but the readjustment of biological equilibrium might result in the evolution of new varieties and possibly new species.

D. A second kind of environmental change would result when from any cause the relations between the basins as a whole and the ocean outside were changed. Such change might occur by the opening of a new passage to the exterior or by the closure of established passages resulting in deflection of currents of the ocean. But the biological effect would be of a different nature to that in the previous case. The general biological equilibrium would be broken. Not only would new species and genera be introduced, but the breaking of the established equilibrium among the species would result in a specific advance in evolution all around; and we might expect,

occasionally, also new genera to arise as the result of such disturbance.

From these considerations it becomes evident that geological phenomena affecting the topographical conditions of the surface of the earth have, from a biological point of view, varying values.

There have been, in the course of geological time, movements of the earth's crust in one direction, continuously, for sufficiently long periods to lift to mountain proportions the edges of continents. These may properly be called *geological revolutions*, and mark such grand changes as separate the Paleozoic from the Mesozoic, and the Mesozoic from the Tertiary. They probably disturbed the biological equilibrium of the marine faunas throughout the greater part of the earth's surface.

There occurred lesser changes, such as the supposed case of the Oriskany, which disturbed the equilibrium of the faunas within confined provinces, destroying old species, introducing new species, and otherwise inducing modification of the species which survived. These were *geological crises* and were local in their effects.

The lesser changes, resulting in rearranging the local environment along a common shore, or in a common basin, were of less consequence and were of more or less continuous operation, causing the shifting of faunas back and forth with resulting slight changes in the varietal and, possibly, specific character of the species, but chiefly expressed in rearrangement of the dominant and secondary species, in the abundance, and sometimes the presence and absence of species from a fauna whose general features remained intact.

To apply these biological principles to the interpretation of geological events it is proposed that, while occasional modification of forms of specific value may have occurred during the ordinary shifting of local conditions marking different *epochs*, the *crises* which disturbed the biological equilibrium of existing marine faunas were the times when the chief modifications of specific and generic value took place; the interval between two such crises represents a biological *period*. Those changes, marked by the extinction of genera and the introduction of new types of family or higher rank among marine species, were of the nature of *revolutions*, in which vast changes were made in the surface conditions of the earth, particularly in the way of lifting tracts of the ocean bottom to a permanent sub-aqueous position and in separating the great geological *eras* from one another. Hence in the study of the geological history of the earth the crises, as well as the revolutions, become of prime importance, and in studying the relations of fossil faunas it is important to discover the territory affected by a crisis, and the particular locality where the effect of the crisis was centered.

ART. XL.—*Note on the Genus Lingulepis*; by
CHARLES D. WALCOTT.

Lingulepis, Hall.

- Lingulepis*, Hall, 1863. Sixteenth Ann. Rep. N. Y. State Cab. Nat. Hist., p. 129.
Lingulepis, Meek and Hayden, 1864. Pal. Upper Missouri, Pt. I, p. 1.
Lingulepis, Hall, 1867. Trans. Albany Institute, vol. v, p. 106.
Lingulepis, Hall and Clarke, 1892. Eleventh Ann. Rep. State Geologist, New York. (Author's Ed.) p. 231, pl. 1, figs. 16, 17.
Lingulepis, Hall and Clarke, 1892. Pal. New York, vol. viii, Pt. 1, pp. 59, 163.
Type, *Lingula acuminata*, Conrad sp.—*Lingula pinniformis*, Owen.

A COMPARISON of a series of specimens of *Lingulepis acuminata* from the Potsdam terrane and the base of the Calcareous formation of Saratoga, Washington, Franklin, and Jefferson counties, New York, and from the same horizons in Ontario, Canada, with a large series of specimens from the St. Croix sandstone of Wisconsin, leads to the conclusion that *Lingulepis pinniformis* is a synonym of *Lingulepis acuminata*. This makes *Lingulepis acuminata* the type of the genus *Lingulepis*, the original description of the genus being based upon specimens from the St. Croix sandstone of Wisconsin.

The further study of the types of the species that have been referred to the genus *Lingulepis* results in the elimination of all of them from the genus with the exception of *Lingulepis acuminata* and *Lingulepis meeki*.

The species that have been referred to *Lingulepis* heretofore are now referred as follows :

- Lingulepis dakotensis*, M. and H.—*Lingulepis acuminata*.
Lingulepis pinniformis, Owen.—*Lingulepis acuminata*.
Lingulepis minima, Whitfield.—*Lingulepis acuminata*.
Lingulepis perattenuata, Whitfield.—*Lingulella perattenuata*.
Lingulepis cuneolus, Whitfield.—*Lingulella cuneolus*.
Lingulepis ella, H. and W.—*Lingulella ella*.
Lingulepis matinalis, Hall.—*Lingulella ? matinalis*.
Lingulepis mæra, H. and W.—*Lingulella ? mæra*.
Lingulepis ? minuta, H. and W.—*Obolella ? minuta*.
Lingulepis morsensis, Winchell (Miller)—*Lingula morsii*.
Lingulepis prima, M. and H.—*Dicellomus polita*.

In a review of the Cambrian Brachiopoda, now being prepared, the Cambrian species referred to the genus *Lingulepis* will be fully illustrated.

Lingulepis meeki, n. sp.

Shell small attenuate, marked by rather strong concentric lines and striae of growth, and interrupted irregular radiating striae.

Ventral valve narrow, elongate; beak acuminate, rostral slopes long, nearly straight, passing gradually into the curvature of the anterolateral margins, and posteriorly meeting at a very acute angle; front strongly rounded. Length of valve 8^{mm}, width 3.5^{mm}, the widest portion being near the anterior extremity. Beak slightly upcurved, the longitudinal median line straight or even slightly concave from the apex of the beak to the middle, where it begins to slope gently to the frontal margin; transverse curvature very slight anteriorly, more convex near the beak.

Dorsal valve more convex than the ventral, linguliform; beak depressed, bluntly rounded, curving evenly and gradually to the semitruncate anterior margin.

The interior markings of this shell have not been ascertained, but the external characters are such as to make a reference to the genus *Lingulepis* more than probably correct. The flat, acute-acuminate ventral valve with its elevated or retrorse beak, which is not covered by the smaller dorsal shell, is peculiarly characteristic of *Lingulepis*.

There is a form from Texas probably identical with *Lingulella perattenuata* that might be mistaken for this species, but it is an undoubted *Lingulella* and does not show the external characteristics of *Lingulepis*. A comparison of *L. meeki* with the young and narrow specimens of *L. acuminata* shows it to be clearly distinct from that species; the posterior rostral slopes of *L. acuminata* possess a peculiar incurving which is not shown in *L. meeki*.

Formation and locality.—Middle Cambrian, upper beds of Flathead Terrane, Crowfoot Section, Gallatin Range, Yellowstone National Park.

ART. XLI.—*Seiches on the Bay of Fundy*;* by A.
WILMER DUFF.

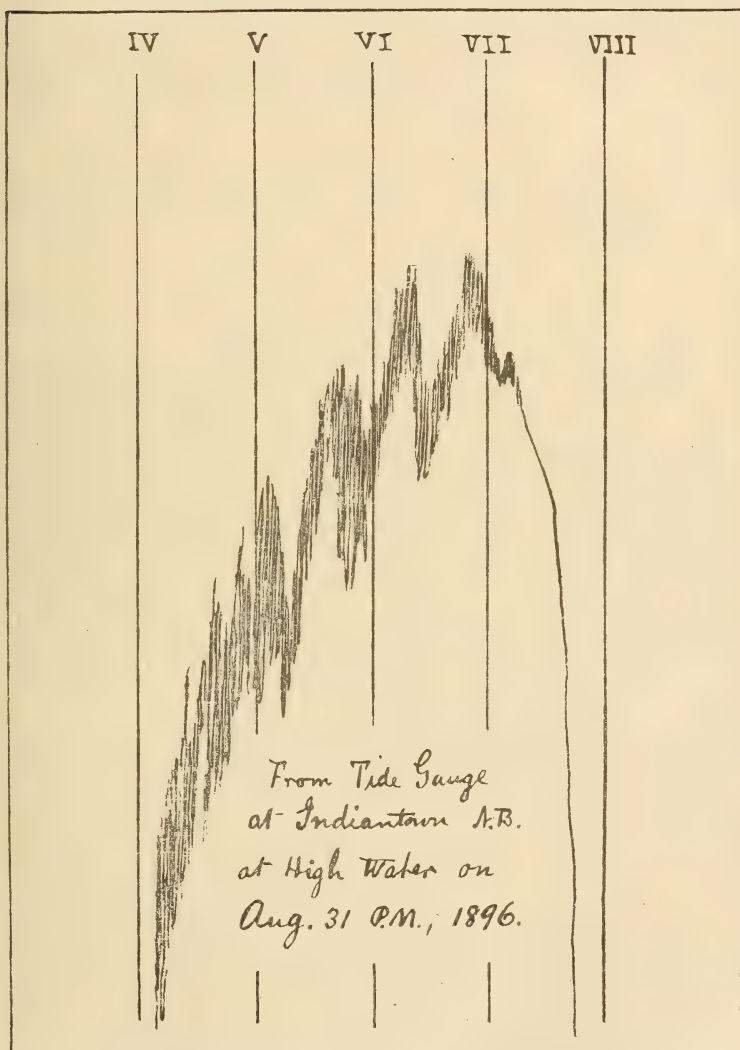
REFERENCE has been made by several writers on tides to so-called "secondary undulations" recorded by self-recording tide-gauges. The most recent mention of the matter is that of Mr. W. Bell Dawson, engineer in charge of the Dominion of Canada Tidal Survey. He notes† these "secondary undulations" on the records of the Kelvin tide-gauge in the harbor of St. John, New Brunswick, on the Bay of Fundy. "They stand," says Mr. Dawson, "in much the same relation to the main tidal wave as a high octave would to a low musical note, when their undulations are recorded graphically. They have an amplitude which is sometimes over a foot, and a period of about forty minutes. It does not seem that any satisfactory explanation has yet been given to account for them."

The same matter came to my attention in the summer of 1896 in such a way as to suggest an explanation. While engaged with a simple form of self-recording tide-gauge in making some tidal observations on the St. John River, I obtained at a point near the mouth of the river the curious trace of high water shown in the adjoining figure. The station at which it was obtained was Indiantown, a part of the city of St. John, immediately above the very narrow outlet (only one hundred yards wide), through which the large river rushes into St. John Harbor. The day on which it was obtained (Aug. 31), was a very calm one. While watching the instrument before high tide I noticed curious little fluctuations of level, having a fairly constant period of thirty-five seconds, as determined by a stop-watch. This period I knew would be sufficient to enable the fluctuations to give a record on the drum of the instrument, whereas mere steamer waves succeeding each other at irregular intervals of a only a few seconds could not, owing to the smallness of the opening through which the water obtained access to the float, give any such trace. These 35-second undulations show themselves in the fine tracings on the left of the record. But what was quite unexpected was the series of larger undulations shown in the record and having a period of between thirty and forty minutes. It will be noticed that both series cease at nearly the same time, about half an hour after high water at Indiantown, that is about two and a half hours after high water in St. John Harbor (for the

* Abstract of a paper read before the Natural History Society of New Brunswick.

† Trans. Roy. Soc. Can., vol. i, 1895-96.

narrow gate between the harbor and the river produces a delay of two hours in high water and low water at Indiantown, which is less than a mile from the harbor). This simultaneous ceasing of the two series of undulations seems to suggest a connection between them.



As regards the slower undulations, it seemed very probable, from the similarity of the period, that they were merely the secondary undulations in the harbor, noted by Mr. Dawson, propagated into the river. These secondary undulations have usu-

ally been regarded as having some connection with the tides proper. As regards the 35-seconds undulations such a connection was clearly impossible, when regard was had to their very brief period. They evidently could not be *forced* vibrations, and if not they must be the *free* vibrations of some semi-confined body of water. Now this body could only be the small bay into which the river expands at Indiantown, nearly closed above by a part called the Narrows, and below by the narrow outlet referred to. This suggested at once that the slower undulations in the harbor had a similar origin, namely, that they were the free vibrations in another semi-confined basin. This basin could not be the harbor itself. Its dimensions are about those of the small bay at Indiantown, and its time of free swing could not be sixty times as great. The only other basin available for an explanation was the Bay of Fundy itself, limited on one side by the New Brunswick coast and on the other by the Nova Scotia coast. Hence it seemed probable that the "secondary undulations" in the harbor were the free vibrations of the Bay of Fundy along a line from St. John to the nearest part of the Nova Scotia coast. The rate of such vibrations depends on the dimensions of the basin, and this provides a means of testing the above theory.

Before applying this test, attention may be called to some similar phenomena observed long since but only recently come to my knowledge. For a great many years certain fluctuations of water level at points on Lake Geneva were known and popularly called *seiches*. After many scattered observations by Bertrand, de Saussure, Vaucher and others, a thorough study of the subject was undertaken by Dr. F. A. Forel, whose two articles* give a complete résumé of the subject. Vaucher had found that the *seiches* were most common in changeable weather, with a low barometer, and he considered them to be due to merely local temperature and consequent barometric changes, caused by rifts in clouds and variations of sunshine on the lakes. Forel added the idea that, after the disturbance of equilibrium produced by the above causes, the *seiches* are simply the subsequent vibrations of the whole lake about its equilibrium position. This theory he tested by making observations on several lakes with the use of self-recording gauges and proving the following laws:† (1) At any one place the *seiche* period is somewhat variable, but the mean is fairly constant; (2) While the water is falling at one side of a lake it is rising at the opposite side, and *vice versa*; (3) The period in the different lakes varies as the width, and inversely as the square root of the depth. He even predicted a depressed area in

* Annales de Chimie et Physique, ix, 1876.

† Phil. Mag., Series V, vol. ii, 1876.

Lake Wallenstadt because of the *seiche* period not agreeing with (3) and discovered it by soundings. He also found both vibrations parallel to the width and vibrations parallel to the length of certain lakes.

The laws of such vibrations as the above have been established both theoretically and experimentally. If t be the time of vibration, parallel to a side of length l , of the water contained in a shallow rectangular vessel with vertical sides and horizontal bottom, and of depth h , then

$$t = 2 \left(\frac{\pi l}{mg} \coth \frac{m\pi h}{l} \right)^{\frac{1}{2}}$$

in which for fundamental or binodal vibrations $m=1$, for trinodal $m=2$, etc. When h is very small compared with l

$$t = \frac{2l}{m\sqrt{gh}} \text{ nearly.}$$

The above is considered to be a first approximation to a solution when the depth is variable, if h be understood to mean the average depth. Thus Forel's law (3) is completely in accord with theory.

Forel's proof of his theory was accepted as sufficient by Sir G. B. Airy.* The latter in reducing tidal observations from Malta found in them oscillations of a sensibly uniform period of 21 minutes and of magnitude considerably greater, at times, than the tides themselves. They were usually simple harmonic curves but sometimes *notched* at the top by smaller oscillations. Airy ascribed the Malta undulations to vibrations between a certain sand bank on the African coast and another on the Sicilian coast, and states that a rough calculation seemed to verify this. He also refers to similar records at Swansea.

No one else seems to have devoted much time or attention to studying the vibrations of large bodies of water, although a number of random observations have been made. As the subject seems worthy of attention, I give in a foot-note references to the literature of the subject.† In two respects, at least, the

* Phil. Trans. Roy. Soc., 1878.

† Forel, Airy, Dawson—see references already given.

J. H. McFarland (Nature, Mar. 12, 1895), observed *seiches* on Lake Derravaragh.

Charles Rhodes (Science, May 7, 1886), observed fluctuations at Oswego.

J. LeConte (Overland Monthly, 1883), predicted *seiche* period of Lake Tahoe.

Ledyard (Science, Feb. 7, 1890), observed 10-min. pulsations on Lake Cazenovia.

T. D. Graham (Proc. A. A. A. S., 1883), found tides on Lake Michigan but apparently no *seiches*.

Smithsonian Contributions, vol. xii, mention fluctuations on Lake Superior.

M. P. Du Boys (Comptes Rendus, tome xii, No. 21, 25 Mai, 1891).

Century Dictionary (under "*Seiche*"), refers to similar phenomena on the Baltic.

question seems of importance. (1) A determination of *seiche* period will afford an estimate of mean depth and may assist in checking soundings or even discovering areas of depression, such as Forel found in Lake Wallenstadt. (2) Many, at least, of the often noted but (except for Airy's apparently half-forgotten remark) unexplained "secondary undulations" may be merely *seiches* on salt water. The Bay of Fundy offers special advantages for testing this latter point. The care with which it has been sounded and its great tidal range (at St. John 27 feet at springs), should enable us to apply the three following tests: (1) Calculation should give a vibration period agreeing with the period of the "secondary undulations." (2) This period should be greater at low water, owing to the less depth, than at high water. (3) Opposite sides should move in the same or in opposite phase, according as the vibrations have an odd or an even number of nodes.

Let us first make a calculation for the small bay at Indian-town. From the chart of the river we have, for the width at the point of observation (Marble Point), 2,030 feet. This is also about the width for some distance farther up; immediately below, there is a great increase of width, due to a small cove; but as this cove is very shallow while the main basin is unusually deep, it will have no practical effect on the period of vibration. For the mean depth we have the following soundings (in feet), along the shortest line to the opposite bank, 56, 60, 78, 94, 108, 136, 124, 108 the mean of which is 95 feet. Immediately above and below, the depth is slightly greater, in one place, 196 feet. Remembering that the formula for calculation is only approximate, it will suffice if 100 feet be taken as mean depth. Substituting these figures in the first formula, we get for binodal vibrations a period of 72 seconds and for trinodal 37.5 seconds. This seems to point to the 35-second pulsations being trinodal vibrations. (The less accurate formula would have given a period of 35.8 seconds.) As the tidal range is less than two feet this period should not appreciably vary with the tide.

In the case of the "secondary undulations" in the harbor, we have, for the width of the bay along a line from the tide-gauge station at St. John to the nearest point of the Nova Scotia coast, 39.8 miles. There will be a slight error in taking this as the width of the basin, for, while the Nova Scotia coast is nearly straight and unbroken, St. John harbor forms an indentation on the New Brunswick side. As it is uncertain how much deduction should be made on this account (perhaps about two miles), the above figure will be used as it stands. From the chart we obtain the following (low water) soundings between St. John and the opposite coast: 10, 4, 5, 9, 21, 27,

33, 36, 38, 40, 42, 43, 47, 50, 50, 45, 43, 43, 46, 46, 40, 40, 39, 35, 27 fathoms, or a mean of 34.4 fathoms. Reducing to feet and substituting in either formula we have, for binodal vibrations, a period of 87 minutes, and for trinodal, 43.5 minutes. Now the period of the "secondary undulations" is, according to Mr. Dawson, "about 40 minutes." If an allowance of two miles had been made for the depth of the indentation referred to, and the corresponding soundings omitted, the calculated period for low water would become very nearly 40 minutes. On the other hand, it will be shown below that the observed period is possibly more nearly 43 minutes. In any case the evidence that these "secondary undulations" are also trinodal vibrations seems strong if not conclusive.

Next, as to the difference of vibration period at high water and at low water, it can be calculated that for a difference of 20 feet (about the mean range at St. John), the period should be two minutes less at high water than at low water. To enable me to test this point, Mr. Dawson has kindly supplied me traces of all the records of secondary undulations at present available and sufficiently well defined to give a reliable estimate. Unfortunately these can hardly be considered sufficient to establish the point, but such as they are, they are given. For low water the periods are 41, 45, 45, 39, 40, 32, 49, 53, giving a mean of 43 minutes; for high water, 43, 35, 43, 40, 46, giving a mean of 41.4. The former mean is 1.6 minutes greater than the latter, but the data are insufficient to justify much reliance being placed on this argument. The apparent variability of period shown by the above figures may be readily accounted for. In the first place every slight barometric change or change of wind produces a corresponding change of level and this is superposed on the "secondary undulations," producing an apparent variation of period. Secondly, the irregularities of coast line may have an effect. Thirdly, and perhaps most important of all, different modes of vibration may co-exist in different proportions at different times, so that the resultant period may at some time be more nearly that of binodal vibration, at others of trinodal, etc. Thus, a higher mode of vibration co-existing with the prevailing mode might account for the "notches" observed by Airy in the secondary undulations at Malta.

As regards the relation of the phases of vibration at opposite sides of the bay, no information is at hand. St. John is the only point on the bay at which there is a recording tide-gauge. Another at Digby, on the opposite side of the bay, would probably settle the matter in a month; but the cost of erecting a gauge suitable for such work is considerable. I hope on some occasion, when the water is calm and "secondary

undulations" exist at St. John, to be able to obtain a record near Digby by use of a small portable gauge.

If the preceding explanation of "secondary undulations" prove correct, it will be a question of interest why the undulations here treated of are trinodal, while those of the lakes observed by Forel are chiefly binodal. No light seems thrown on the question by present hydrodynamical theory. The explanation may perhaps be found in the fact that a lake is a completely enclosed body of water, while a bay is open at one side or two opposite sides. If, as seems possible, the smaller undulations across the basin at Indian town are produced in some way by the larger ones of the harbor entering at one end of the small bay, the result would more probably be a simultaneous elevation at opposite sides than an elevation at one and a depression at the other. This suggests that the undulations across the Bay of Fundy may in some similar way be produced by the uprush or downrush of the tides. They do not seem (as in the case of the Swiss *seiches*) to be connected with abnormal conditions of barometer; at least no such connection appears to exist in the cases whose periods are given above.

Addendum. In a recent article (Phil. Mag., Jan. 1897), Mr. C. Davison has pointed out that a considerable error may be made in extending the formula for a basin of uniform depth to one of irregular depth. In fact the true period of the trinodal vibrations considered in the preceding is

$$\int_0^l \frac{dx}{\sqrt{gy}}, \quad (y = \text{depth}).$$

Changing this to the form

$$\frac{l}{\sqrt{g}} \times \left(\text{mean } \frac{1}{\sqrt{y}} \right),$$

I have calculated its value for trinodal vibrations across the Bay of Fundy, at St. John (allowing two miles as before) and find that it gives a period of 42.2 minutes.

Purdue University, Lafayette, Ind.

ART. XLII.—On *Ræblingite*, a new Silicate from Franklin Furnace, N. J., containing Sulphur Dioxide and Lead; by S. L. PENFIELD and H. W. FOOTE.

MR. FRANK L. NASON, who has been especially interested in the geology and mineralogy of the zinc deposits of Franklin, New Jersey, has recently brought to our attention a mineral from the Parker shaft of the New Jersey Zinc Company, which owing to its unusual chemical composition is of especial interest. The mineral occurs in dense, white, compact masses, which consist of an aggregate of minute prismatic crystals. These when examined with the microscope show parallel extinction and a weak double refraction, but they are so minute that the system of crystallization could not be determined. The specific gravity is 3.433; hardness a trifle under 3. A chemical analysis of this material by Foote gave the following results:

| | I. | II. | Average. | | Ratio. | |
|-------------------------|-------|-------|----------|------|--------|--------|
| SiO ₂ | 23.51 | 23.66 | 23.58 | .393 | 5.61 | 5.0 |
| SO ₂ | 9.01 | 8.99 | 9.00 | .141 | 2.01 | 2. |
| PbO | 31.07 | 30.99 | 31.03 | .139 | 1.99 | 2. |
| MnO | 2.46 | 2.51 | 2.48 | .035 | } .520 | } 7.43 |
| CaO | 25.91 | 25.98 | 25.95 | .463 | | |
| SrO | 1.33 | 1.46 | 1.40 | .014 | | |
| K ₂ O | .16 | .09 | .13 | .001 | | |
| Na ₂ O | .43 | .36 | .40 | .007 | } 5.04 | } 5. |
| H ₂ O | 6.36 | 6.35 | 6.35 | .353 | | |
| | | | 100.32 | | | |

The ratio of SO₂:PbO:H₂O is very close to 2:2:5, but that of the SiO₂ and the remaining bases to these constituents is not so simple. The nearest approach to a simple ratio is perhaps SiO₂:SO₂:PbO:RO:H₂O = 5:2:2:7:5, and this gives the rather complicated formula H₁₀Ca₇Pb₂Si₅S₂O₂₅. The water is driven off at a rather high temperature and is therefore to be regarded as hydroxyl. The formula given above may be regarded as a combination of five molecules of a silicate H₂CaSiO₄ and two of a basic sulphite CaPbSO₄ or (CaO. PbSO₃). The theoretical composition for this formula is given below, together with the results of the analysis after substituting for MnO, SrO and the alkalis their equivalent of CaO and recalculating to 100 per cent.

| | Found. | Theory. |
|------------------------|-------------|-------------|
| SiO ₂ ----- | 23.8 | 22.1 |
| SO ₂ ----- | 9.1 | 9.4 |
| PbO----- | 31.3 | 32.9 |
| CaO----- | 29.4 | 29.0 |
| H ₂ O----- | 6.4 | 6.6 |
| | <hr/> 100.0 | <hr/> 100.0 |

There must be some question as to the exact formula of the mineral, for the one proposed is complicated and the agreement between the results of the analysis and the theory is not so close as one would desire. It is not probable, however, that the mineral is a mixture, or, at least, that it contains much foreign material. If it were a mixture, one would expect the presence of some heavy lead mineral, considerably above 3.43 in specific gravity, with a lighter calcium silicate. In order to test this point some of the material was powdered, sifted to a uniform grain and placed in methylen iodide with a specific gravity of 3.29 when all of the powder sank. It is thus very definitely proved that wollastonite (specific gravity 2.9) or any related calcium silicate is absent.

The special points of interest connected with this mineral are that this is the first time that a sulphite has been observed in nature, and that silicates containing lead are very rare, having been observed up to the present time in only a few localities in Sweden.

The mineral fuses before the blowpipe at about 3 to a gray globule, and gives the pale blue flame of lead, which ceases after heating for some time. On charcoal with sodium carbonate in the reducing flame, lead globules and a coating of lead oxide are produced, and the residue reacts on silver for sulphur. With the fluxes, the reactions for manganese are obtained. In the closed tube, water is given off. The powdered mineral is dissolved with ease in acids, even when very dilute, and gelatinous silica is obtained upon evaporation. The odor of sulphurous anhydride may be obtained when the mineral is dissolved in a little hydrochloric acid, but this test is not very apparent.

Concerning the occurrence of the mineral, the following information has been received from Mr. Nason: The mineral occurs at the one thousand foot level, in or near the contact between granite and white limestone, where great veins and bunches of garnet rock are found. The associated minerals are garnet, titanite, zircon, phlogopite, axinite both massive and in drusy crystals, willemite in small, green, transparent crystals, datolite, barite, caswellite, calcite, arsenopyrite, sphalerite, rhodonite and rhodochrosite. The axinite, which occurs

in veins and pockets in the garnet rock, is in places porous and full of cavities and these are completely filled at times with the masses of rœblingite. The largest mass that was found weighed about five pounds and was about the size and shape of a coconut.

The ore body and the rocks in the mine are greatly shattered and show frequent slickensides, and undoubtedly the agencies which produced the shattering movements were the ones which also produced the conditions necessary for the formation of the great variety of minerals observed at this locality.

The method used in analyzing the mineral is as follows:

The mineral was dissolved in nitric acid, and silica removed in the ordinary way, substituting nitric for hydrochloric acid, so that lead might not remain behind. When heated in the air bath at 140° , however, some manganese nitrate was decomposed and converted into a higher oxide which was insoluble in nitric acid. This was filtered off with the silica, and after washing, was dissolved by treatment with hydrochloric acid. The nitric and hydrochloric acid filtrates were evaporated to dryness separately and a further trace of silica was thus removed. Lead was precipitated from the slightly acid solution by hydrogen sulphide and determined as sulphate, and manganese and calcium were determined by the ordinary methods. The small amount of strontium was weighed with the calcium as oxide and separated by treatment with amyl alcohol. For the determination of sulphur dioxide, separate portions were used. The mineral was treated with strong bromine water and hydrochloric acid, and after being dissolved and standing for some time, the sulphuric acid formed was precipitated as BaSO_4 . The precipitate was impure, containing silica and probably some lead sulphate, and it was purified in the ordinary way by fusion with sodium carbonate and reprecipitation with barium chloride. Water was determined directly by means of the closed tube method,* and alkalies by a Smith fusion.

At the request of Mr. Nason the authors take pleasure in naming this mineral rœblingite in honor of the celebrated engineer, Mr. W. A. Rœbling of Trenton, N. J. They also take pleasure in expressing their thanks to Mr. F. L. Nason and Mr. John A. Manley of New Brunswick, N. J., for the pains they have taken in supplying material for this investigation.

Mineralogical and Petrographical Laboratory.
Sheffield Scientific School, New Haven, April, 1897.

* This Journal, III, xlviii, p. 31, 1894.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Rotation of Circularly Polarizing Crystals in the State of Powder.*—It has been shown by LANDOLT that the specific rotation of isotropic circularly polarizing crystalline substances, in a state of powder, may be determined in an ordinary polarimeter tube, by suspending the finely divided material in a liquid having the same refractive index and then measuring the angle through which the plane of polarization of the entering beam is turned. For the best result, the substance should be pulverized in an agate mortar and then sifted, so as to obtain particles of from 0.004 to 0.012^{mm} in diameter; and while the measurements are being made the polarimeter tube should be constantly rotated, so as to keep the particles uniformly suspended. The speed of rotation should preferably be between 50 and 80 revolutions per minute, since at higher velocities the particles of the solid are driven by centrifugal action to the sides of the tube, leaving the central portions more or less empty of them. The direction of rotation of the tube is immaterial. The author's experiments were made with both right and left-handed sodium chlorate, from 0.1 to 0.3 gram of the powder being placed in a test tube with alcohol, carbon disulphide being gradually added until the maximum transparency was reached; this requiring about two volumes of the disulphide to one of alcohol. The mixture was then placed in the tube of the polarimeter and the angle of rotation measured. To determine the amount of solid, the contents of the tube were placed in a platinum dish, evaporated to dryness and the residue weighed. In this way the specific rotation of the sodium chlorate in powder was found to be $[\alpha]_D = \pm 1.41^\circ$; while that of the crystals is given as 1.42° for 1^{mm}, practically the same value. Hence it appears that particles of this salt having a diameter of from 0.004 to 0.012^{mm} possess the same crystalline structure as that to which the circular polarization of the larger and completely formed crystals is due.—*Ber. Chem. Ges.*, xxix, 2404–2412, October, 1896. G. F. B.

2. *On the Oxidation of Nitrogen Gas.*—In his experiments upon the isolation of argon, RAYLEIGH made some observations upon the oxidation of nitrogen, which he has communicated to the Chemical Society. His first experiments were made to test the statement of Davy that the dissolved nitrogen in water is oxidized to nitrous or nitric acid when the liquid is submitted to electrolysis. The water was contained in two cavities bored in a block of paraffin and connected by a wick of asbestos previously ignited. By means of platinum terminals connected with a secondary battery a difference of potential of 100 volts was maintained in the cells, the whole being covered with a glass shade. But under these conditions, litmus showed no difference between

the two portions of water, even after fourteen days. If however the shade was removed the litmus responded in a day or two. Nor did the action of sodium peroxide, either with or without acid, effect the oxidation of dissolved nitrogen. His later experiments were directed to test the effect of pressure in the oxidation of nitrogen by oxygen gas under the action of the electric discharge. A suitable mixture of nitrogen and oxygen, standing in an inverted test tube over alkali, was sparked from a Ruhmkorff coil driven by five Grove cells; and it was found that under a total pressure of three atmospheres the mass absorbed was about three times that absorbed in the same time under the ordinary pressure. He therefore proceeded to repeat the operation on a larger scale, using a vessel of 250^{cc} and the alternate current discharge. To protect the glass, the top of which came nearly in contact with the electric flame, as well as to facilitate the absorption, the alkali was thrown on to the glass immediately above the flame in the form of a fountain, thus washing the entire internal surface. At atmospheric pressure, however, the absorption was but 1600^{cc} per hour; only one-half the rate already obtained. On increasing the capacity of the working vessel, the efficiency improved. With a bottle of 370^{cc} capacity, a rate of 2000^{cc} per hour was attained. With a larger flask, one of 3300^{cc}; while a globe of 4½ liters gave a rate of 6800^{cc} per hour. In this latter case, ten amperes passed through the primary and there was a potential difference of 41 volts at its terminals. To test the question of pressure, a glass globe having a capacity of about 7 liters was used, under a pressure of nearly an additional atmosphere, this pressure being obtained by gravity, the feed and return pipes for the alkaline fountain as well as the pipe for the supply of water to the gas-holder being carried to a higher level than that at which the rest of the apparatus stood. The rate of absorption (reduced to atmospheric pressure) was 6880^{cc} per hour, that conducted at the ordinary pressure being 6600^{cc}. Under half an atmosphere the absorption was 5600 and 5700^{cc} per hour. Hence it would appear that pressure is of advantage only where the space is too confined to admit of the best efficiency at a given pressure being reached. The author next sought to obtain a high rate of absorption by employing a powerful electric flame contained in a large vessel whose walls were washed internally by an alkaline fountain. The flame was obtained by means of a Swinburne transformer insulated with oil, which gave on open secondary nearly 8000 volts; but which when the discharge was passing fell to 2000. In its primary circuit a self-induction coil was placed provided with an adjustable core of iron wires. When in operation the potential difference at the primary terminals was only 30 volts, the current passing being 40 amperes. But since the reduction-factor—the cosine of the angle of lag—is about two-thirds, the watts expended are only about 800 in place of 1200, the product of 30 by 40; so that the rate of energy consumption was a little more than a horse-power. The working vessel was

globe-shaped and of 50 liters capacity. The neck, placed downwards, was closed with a rubber stopper carrying five glass tubes. Two of these were heavy and carried the electrodes. Two others supplied and drained the fountain and the fifth furnished the gas-mixture, 11 parts of oxygen to 9 of air, contained in a large gas-holder. The rate of absorption was about 21 liters per hour, thus giving about 25° per watt-hour. So that this apparatus works about three times as fast as the former one in which the vessel was smaller and the alkali stationary within it.—*J. Chem. Soc.*, lxxi, 181, February, 1897.

G. F. B.

3. *On the Presence of Nitrites in the Air.*—A quantitative examination of the air for nitrites has been made by DEFREN. Re-distilled water, free from ammonia, nitrites and nitrates, was exposed to the air in well ventilated rooms in porcelain evaporating dishes 15^{cm} in diameter. Each dish contained 100^{cc} of water, the superficial area exposed being 95^{sq cm}. The water was examined at intervals for nitrites, the quantity being computed by comparison with a standard solution of potassium nitrite containing, per cubic centimeter, 0.0000001 gram of nitrogen as nitrite, the circumstances as regards burning gas jets and lamps being noted. Under varying conditions the quantity of nitrite found, in terms of cubic centimeters of standard, was after one hour, 2.5, 3.5 and 8; after two hours 3.5, 8.5 and 13.5; after 17 hours in the last instance 84.2; and after nineteen hours in the first and second instances 57.2 and 72.7 respectively. These results show that nitrites exist in the air where gas is burning, even in well ventilated rooms; and also that water absorbs these nitrites in quantities increasing with the time of exposure to the polluted air.—*Chem. News*, lxxiv, 230; *J. Chem. Soc.*, lxxii (ii), 94, February, 1897.

G. F. B.

4. *On the Solubility of Lead and Bismuth in Zinc.*—In their investigations on the solubility of lead and bismuth in zinc, SPRING and ROMANOFF used a crucible having a hole bored in the side at a convenient distance from the bottom, and stopped with a plug during the preparation of the solution. The heavier metal is first poured into the crucible so that its level is just above the opening. Then the zinc is added and covered with a layer of fused salt or charcoal to protect it, the crucible being maintained at the temperature at which the solubility is to be determined, the contents being stirred every ten minutes. By means of a ladle a sample of the top layer is now taken. On knocking out the plug in the side, the top layer runs out and a sample of the bottom layer is ladled out. The two samples are analyzed, a table being given of the composition of the two layers at temperatures from 266° to 900°. Plotting the temperatures as abscissas and the percentages of the two layers as ordinates, two points are obtained for each temperature. One of these is the solubility of bismuth in zinc, the other the solubility of zinc in bismuth. By prolonging these until they meet, the temperature is found at which the two metals will mix in all proportions. The

critical temperature for bismuth and zinc is between 800° and 850° and that for lead and zinc between 900° and 950° .—*Zeitschr. anorg. Chem.*, xiii, 29–36, 1896. G. F. B.

5. *Traité Élémentaire de Mécanique Chimique fondée sur la Thermodynamique*. P. DUHEM, Tome I, 299 pp, Paris, 1897. (Hermann).—This is the first volume of a work which promises to be extensive, although there is no intimation here of what the author's complete plan may be. A short introduction, reviewing certain mathematical conceptions and forms of notation, which are used later, is followed by a division constituting somewhat more than half the whole volume treating of the fundamental principles of thermodynamics, and by a second on "false equilibria" and explosions. The novel term false equilibrium is defined as a state of equilibrium which is experimentally realizable although the theory of thermodynamics hitherto developed declares it impossible.

An abstract from the author's preface will serve to give a better idea of his aims than any criticism of the more or less considerable fragment before us.

After attributing to Berthollet the enunciation of the truth that a study of the laws which govern chemical combinations and decompositions is inseparable from the study of those which govern changes of physical state, which more comprehensive study constitutes the science of chemical mechanics, he writes: "Berthollet, in accordance with the ideas prevalent at his time, demanded the principles of this science from Statics and Dynamics Sainte-Claire-Deville recognized that the principles of chemical mechanics must be sought in Thermodynamics; developed and defined by Horstmann, by Montier, by Gibbs, by Helmholtz, by a host of other physicists, his idea has given birth to a body of doctrines ample and fruitful, the *chemical mechanics founded upon thermodynamics*. It is this body of doctrines which we propose to develop."

6. *Elements of Theoretical Physics*; by DR. C. CHRISTIANSEN, translated by W. F. Magie, Ph.D., 339 pp. New York, 1897. (The Macmillan Company).—This is a book covering a wide field in mathematical physics and is certain to prove useful. The style is condensed but clear and direct. The translator's work is so well done—from the German of Müller—that a reader would possess unusual critical faculties who could recognize its source as other than in a writer of English.

A book of such moderate size and covering so wide a range of subjects must of necessity be very concise, far too much so to be of easy digestion by even the cleverest students. As an illustration of this condensation we may cite Chapter xii, Refraction of light in isotropic and transparent bodies. This contains an introduction followed by sections on Fresnel's formulas; the electromagnetic theory of light; equations of the electromagnetic theory of light; refraction in a plate; double refraction; discussion of the velocities of propagation; the wave surface (two sections);

the direction of the rays; uniaxial crystals; double refraction at the surface of a crystal; and double refraction in uniaxial crystals, all of which are contained in thirty-seven pages. The chapter which precedes this treats somewhat compendiously of electrical oscillations in a space of less than fifteen pages. It is clear that a student can hardly be expected to master these portions of mathematical physics with no other help, but, on the other hand, as an aid in coördinating his knowledge and as a guide in the choice of a rational and consistent system of notation the book is of very great value.

7. *Theory of Physics*; by JOSEPH S. AMES, Ph.D., pp. xvii + 513. New York, 1897. (Harper & Bros.)—As stated in the author's preface, this book is designed for use as a text-book by college classes in elementary physics in connection with a course of experimental lectures and recitations. The methods of presentation are clear, the arrangement logical and, as a whole, the book seems well adapted to its purpose. The portion dealing with mechanics is especially to be commended; the definitions are consistent and philosophical, and the way in which the analogies between translation and rotation are brought out and insisted upon is admirable.

The section upon electricity and magnetism is largely written from the Faraday-Maxwell point of view, and the ether is frequently referred to as the medium of electrical actions; it seems strange, however, to find no mention made of the sole ground for this belief; viz. the entire similarity between light and electrodynamic action. So great a generalization would seem to merit some discussion even in an elementary text-book, published twenty-five years after Maxwell and nearly ten years after Hertz.

Problems in the reflection and refraction of light are mostly treated by considering wave surfaces and their curvatures instead of rays and focal lengths. This treatment is much to be preferred, not only because of its direct reference to the nature of light, but also because it leads to methods of much greater elegance and power in the solution of complicated optical problems.

The work, as a whole, is a decided improvement upon the ordinary text-books of elementary physics and will no doubt be welcomed by teachers of that subject.

H. A. B.

8. *The Outlines of Physics, an Elementary Text-Book*; by E. L. NICHOLS, pp. 452, New York, 1897. (The Macmillan Company.)—This is an elementary treatise for use in preparatory schools. It aims to combine in one volume the laboratory manual and the text-book, being intended for a one year's course. The best feature of the book is that part devoted to the laboratory directions. There are above a hundred experiments, carefully worked out and explained, the apparatus used being simple and inexpensive. The emphasis laid on the tabulation and interpretation of the quantitative results, whenever obtained, is very welcome, on account of its conspicuous absence in most elementary

text-books. The theoretical portions perhaps suffer by contrast with the experimental on the score of lack of concise definitions. To take but one instance, there is apparently no definition given of a fluid, and the distinction between fluids and liquids, though tacily assumed, is not definitely stated. It also might be wished by some that the author had introduced the conception of lines of force in the section on electrostatics and not have left it until magnetism, or rather the magnetic action of a current, was taken up. However, this and other points more or less pedagogical in nature, suggested by the arrangement adopted by the author, are after all matters of personal opinion. The book is admirably adapted to schools with limited laboratory equipment, and is probably in the first rank of its class.

L. P. W.

II. GEOLOGY AND NATURAL HISTORY.

1. *Geological Survey of Canada*.—The following parts of the Annual reports for 1894, 95 and 96 have been issued :

Maps to accompany annual report, vol. vii, 1894. 556 British Columbia—Kamloops sheet geology; 557, same, topography, etc.; 567, same, Finlay and Omenica rivers. 571, Quebec—Southwest sheet, "Eastern Townships" map (Montreal sheet.) 561, New Brunswick and Nova Scotia—Sheet 4 N. W.—(Cumberland Coalfield sheet) Surface geology. 562, same, sheet 2 S. E.—(Richibucto sheet) Surface geology. 563, New Brunswick and Prince Edward Island—Sheet 5 S. W.—(Buctouche sheet) Surface geology.

Part J. Ann. Rept., vol. viii. Report on the geology of a portion of the Laurentian area lying to the north of the island of Montreal; by Frank D. Adams.

Part S. Ann. Rept., vol. viii. Section of Mineral Statistics and Mines. Annual Report for 1895; by Elfric D. Ingall and L. L. Brophy.

Summary Report of the Geological Survey Department for the year 1896, George W. Dawson, Deputy Head and Director. In this last document is found a brief summary of the more important results of the survey during the year. The Director remarks : "During the past year very notable progress has been made in development of the mineral resources of Canada, both in the way of actual work and in attracting the attention and interest of capital. British Columbia has begun to evidence its value as a permanent producer of the precious metals, in a manner long foreseen by those who have paid attention to its geological structure and position. In Ontario, wherever the Huronian system is developed and has been examined, valuable mines—more particularly those of gold—are being discovered and opened up. In Nova Scotia, renewed interest has been shown in gold mining, etc. (p. 7.)

Corundum has been discovered in Hastings Co., Ontario. Investigations in the peninsula of Labrador have revealed Cam-

brian rocks with beds of iron ore. In this region it was found "that the rock-striations indicated a flow of ice, during the glacial period, from the vicinity of the present water-shed, both to the westward and to the eastward, nearly in conformity with the general slope of the surface."

The boring for petroleum at Athabasca landing, Alberta, was carried down to a depth of 1770 feet with great difficulty, and at last the work was stopped by the caving in of the soft shales so as to make further penetration impossible with the tools at hand. The zone of so-called "tar sands" at the bottom of the Cretaceous had not been reached. The Director remarks that the work so far accomplished "has not in the least degree tended to render the existence of petroleum even at Athabasca landing, more doubtful than before." (p. 14.)

Mr. Chalmers reports two glacial clays in the St. Lawrence valley region, and has observed "a series of three shore-lines on the south side of the St. Lawrence, facing the open St. Lawrence valley intermittently extending from the Gulf to the international boundary in the vicinity of Lake Champlain, at heights of 600 to 625 feet, 700 to 720 feet, and 875 to 885 feet (aneroid measurements). These shore lines are believed to be marine and to indicate margins of the sea in the St. Lawrence valley in the Pleistocene period. (p. 82.)

In Mr. Chambers' report we notice also the following interesting fact:—"Dislocations or slips of the slates over each other, along certain zones or bands, since the glacial period, were observed in a great number of places, the displacements ranging in extent from two or three inches to five or six feet. One of the most remarkable examples of these movements in the rocks, was seen in the southern part of the seigniory of Aubert Gallion, Beaver County, where a band of slates from three to four feet thick and several hundred yards in length had sustained an upward shore of nearly six feet above the general level of the glaciated rock-surface, as evidenced by the parallel and well-marked striæ." (p. 83.) This recalls similar phenomena recorded by G. F. Matthew in the suburbs of St. Johns, New Brunswick.

H. S. W.

2. *Boletín del Instituto Geológico de México*—Nums. 4, 5 y 6. *Bosquejo Geológico de México*; by Director JOSÉ G. AGUILERA. pp. 1-272, plates i-v, 1897.—This volume contains detailed reports of reconnaissance surveys (itinerarios geológicos) of the country by several members of the survey staff and a second part by the director presenting the classification of the formations with lists of fossils and descriptions of the rocks comprising them. A brief obituary notice of Ingeniero Antonio del Castillo, the founder and first director of the Instituto Geológico de México, is inserted at the beginning of the volume.

H. S. W.

3. *An introduction to Geology*; by WILLIAM B. SCOTT, pp. 1-563, figs. 1-169, plates i-xii. New York, 1897. (The Macmillan Co.)—Professor Scott has supplied a much felt need, in giving

us an admirable class book in geology, which has enough of detail and not too much for the ordinary college student. In general the subject has been developed with much skill and a good sense of proportion, though in abbreviating the treatment too much has been omitted in some cases. For instance, geysers are dismissed with only ten lines, and discussed quite separate from the chapter on volcanoes, under the general subject of "running waters."

The subjects are treated in chapters, each one of which can be studied by itself, and, in general, sufficient definiteness of statement is given to enable the student to form correct notions of the topics discussed; but to the writer the arrangement seems too discontinuous for the best interests of a class, unless it be used to supplement a course of lectures in which the personality of the instructor appears. A want of continuity of treatment is felt, for instance, in the discussion of glaciers; thus on pp. 104-116, as one of the destructive processes; ice deposits are considered again, pp. 153-159, as reconstructive processes, and ice erosion is discussed again on pages 310-312. Again, the separation of the chapters on land sculpture, adjustment of rivers and cycles of erosion, quite distant from the destructive and reconstructive processes of dynamical geology, makes a break in continuity, which is useful in an exhaustive treatise on geology, but appears somewhat artificial in an introduction to the subject.

The illustrations of the book are chiefly new, fresh and from American sources, in this particular making the book a decided addition to text-book literature. A number of excellent photographs of typical regions and structures are reproduced, many of them admirably, but this method of reproduction has its limitations, such pictures as those of Mauna Loa and Mt. Shasta and some others (as figures 34, 120, 128) are too indistinct to have much scientific value.

H. S. W.

4. *Glaciers of North America*. A Reading Lesson for Students of Geography and Geology; by ISRAEL C. RUSSELL, pp. 210, Boston and London, 1897. (Ginn & Co.)—It is not many years now since very little was known of glaciers on this continent, except those of the Greenland coast in the far north. Recent explorations, however, have shown that there are true glaciers even in the Sierras of California, while those of Alaska have been extensively studied. In this work, particularly in the latter field, the author has done much himself, and the present volume is a very interesting summary of the entire subject, which will appeal to the popular reader as well as to those interested in the strictly scientific side. Of the concluding chapters, one discusses the various hypotheses advanced to account for the movement of glaciers, and another treats of the subject of the life-history of a glacier.

The book is admirably illustrated and the half-tone reproductions from photographs add much to its interest and value.

5. *A Treatise on Rocks, Rock-Weathering and Soils*; by GEORGE P. MERRILL, pp. 411. New York and London, 1897. (The Mac-

millan Co.)—The author rightly remarks that he does not need to apologize for the presentation of this volume, since it deals with a subject which has never been systematically presented in a single volume before. The value of the work is largely increased by the fact that it includes not simply the results that have been given to science by others, but those which the author himself has obtained through a number of years of investigation. The subject is one of the highest interest, not only from the strictly scientific side, but also to those who are concerned with the use of building stones in general.

Part I discusses the mineral constituents of rocks, also their general characters and occurrences. Part II gives a summary and classification of the different kinds of rocks. Part III, which contains the most original portion of the work, is devoted to the weathering of rocks, with a discussion of the various methods by which this is accomplished, and the results in various cases as applied to rocks of different natures. The manifestations of weathering, the rate at which it takes place, and other points are also treated of. Part IV treats of the transportation and redistribution of rock debris. Part V is devoted to the "regolith" or mantle of unconsolidated material which covers a large part of the earth's surface, including both sedentary and transported materials. A particularly interesting portion of this chapter is that given to a discussion of soils in their different aspects.

This brief summary of the contents of this admirable volume will give a partial idea of what it contains, but a thorough appreciation of its value and originality can only be gained by careful perusal. Numerous excellent illustrations accompany the text.

6. *Elemente der Mineralogie begründet von Carl Friedrich Naumann*. Dreizehnte, vollständig umgearbeitete Auflage von Dr. FERDINAND ZIRKEL. I. Hälfte: Allgemeiner Theil, pp. 386. Leipzig, 1897. (Wilhelm Engelmann.)—Twelve years have now passed since the twelfth edition of Naumann's *Mineralogie* was issued by Prof. Zirkel. During this time great progress has been made in the science, as well on the theoretical as on the descriptive side. Mineralogists will, therefore, welcome warmly this admirable treatise in its new and thoroughly revised form. The first half, discussing the crystallographic, physical, and chemical properties of minerals, is now given to the public, and the second half, containing the description of species, is promised by the end of the present year.

7. *An Introduction to the Study of Meteorites*, with a List of the Meteorites represented in the Collection. British Museum (Natural History), Mineral Department, 1896.—Dr. Fletcher has recently given to the public a revised edition of the catalogue of the British Museum collection of meteorites, including a considerable number of specimens not noted in the catalogue of 1894.

8. *Pseudomorphs after halite from Jamaica, W. I.*; by E. O. HOVEY (communicated).—In some material collected in Jamaica, W. I., and presented to the American Museum of Natural History by Francis C. Nicholas are some pseudomorphs after halite which are worthy of note. The outward form is the ordinary cube of the salt crystal with cavernous or hopper-shaped faces, and groups made up of from two to five individuals occur in the series. In most cases the replacing material is calcite with a considerable admixture of clay, in some gypsum (selenite) forms the pseudomorph and in others there is a shell of clayey calcite from less than 0.5^{mm} to several millimeters in thickness, preserving the outward form of the salt crystal and surrounding pure selenite or a mixture of selenite, clayey calcite and iron oxide. The specimens are from a bed of hard, gray clay or shale from a short distance west of Easington, Parish of St. Thomas (formerly St. David) and are of further interest on account of the statement made by J. G. Sawkins in his Reports on the Geology of Jamaica, p. 37, that "deposits of mineral salt are not found in the island." Sawkins (p. 54) mentions gypsum, however, as occurring near Easington in beds between the Carbonaceous shales and the yellow limestone.

9. *Flora of the Southern United States: containing an abridged description of the Flowering Plants and Ferns of Tennessee, North and South Carolina, Georgia, Alabama, Mississippi, and Florida: arranged according to the Natural System*; by A. W. CHAPMAN, M.D., LL.D. Third edition. Cambridge, Mass. Cambridge Botanical Supply Company. 1897.—The title above given indicates sufficiently the nature of this work. The revision incorporates considerable new material, and, still, by judicious abbreviation and condensation, keeps within convenient form. To the increasing numbers of visitors to health resorts in the southern states, and who have anxiously but vainly sought for copies of the two previous editions, the present revision will be very acceptable. There is little doubt that a great deal remains to be done in the elucidation of our southern flora: Dr. Chapman's useful treatise will long serve as a basis for such local research and a most handy work of reference. We trust that the venerable botanist may long be spared to carry out his intention of publishing further issues as occasion may require. G. L. G.

10. *Neural Terms, International and National*; by BURT G. WILDER. (From the Journ. Comp. Neurology, vol. vi, pp. 216-352, 1897.)—This paper, the latest of Professor Wilder's contributions to a revision of anatomical nomenclature, is largely devoted to an unfortunate controversy with Professor Wilhelm His and the "Anatomische Gesellschaft." The principles of Professor Wilder's nomenclature are very fully discussed and elucidated and a useful list of anatomical terms applied to the nervous system is given.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences*.—The following is a list of the papers entered to be read at the meeting of the Academy held at Washington, April 20–22:

ADELAIDE WARD PECKHAM, M.D.: The influence of environment upon the biological processes of the various members of the colon-group of bacilli.—An experimental study.

T. C. MENDENHALL: On the energy involved in recent earthquakes.

T. C. MENDENHALL and A. S. KIMBALL: On a ring pendulum for absolute determinations of gravity.

S. C. CHANDLER: On the variation of latitude.

THEODORE GILL: The position of the Tarsiids and relationship to the phylogeny of Man.

A. A. MICHELSON and S. W. STRATTON: A new harmonic analyser.

J. K. REES, H. JACOBY, and H. S. DAVIS: Variation of latitude and constant of aberration from observations at Columbia University.

A. AGASSIZ: On recent borings in coral reefs.

ARTHUR W. WRIGHT: Notes of experiments upon the Röntgen rays.

S. P. LANGLEY: Biographical memoir of G. Brown Goode.

H. L. ABBOT: Biographical memoir of Thomas L. Casey.

H. P. BOWDITCH: Biographical memoir of Charles E. Brown-Séquard.

J. W. GIBBS: Biographical memoir of Hubert A. Newton.

G. K. GILBERT: Biographical memoir of George H. Cook.

2. *Microscopic Researches on the Formative Property of Glycogen. Part I, Physiological*; by CHARLES CREIGHTON, M.D. Formerly Demonstrator of Anatomy at Cambridge; pp. 152, with five colored plates. London, 1896 (Adam and Charles Black).—Dr. Creighton's work emphasizes the prominence of glycogen in young embryonic tissues, especially at the centers or points of rapid growth and at a time in fœtal life when the vascularity of the part is hardly established. From the observations made, the author inclines to the view that the glycogen of embryonic tissues possesses a kind of intangible power which makes it the forerunner and pioneer of new growths without, however, losing its own molecular identity and without becoming an integral part of the tissue; a view which physiologists will have some difficulty in accepting in its entirety.

R. H. C.

3. *The Tutorial Statics*; by WM. BRIGGS and G. H. BRYAN; pp. 260. London, 1897 (The University Correspondence College Press).—One of the University Tutorial Series, whose object is to provide candidates for the London University Examinations with so much as is necessary to prepare for those tests without offering any opportunity for acquiring superfluous knowledge. Aside from its place in the series there seems no particular reason why it should have been written. It is as good as a number of other recent English books on the same subject, and no better.

W. B.

4. *Royal Society of London*.—Professor J. Willard Gibbs of New Haven has recently been elected a fellow of the Royal Society.

OBITUARY.

EDWARD DRINKER COPE, Professor of Zoology and Comparative Anatomy in the University of Pennsylvania, died at Philadelphia on the 12th of April in the forty-sixth year of his age. Professor Cope had devoted his life to research in the fields of zoology and paleontology, chiefly, of vertebrates.

Beginning his career as a medical student in the University of Pennsylvania, he continued his studies in comparative anatomy in the Philadelphia Academy of Sciences, the Smithsonian Institution and in Europe. In 1866 he became a professor in Haverford College. He was on the Geological Survey of Ohio in 1868. For many years after this he was engaged in explorations in the west; in connection with the Hayden Geological Survey, 1872, etc., with the Wheeler Geographical Survey, 1874, and thereafter either at his own expense or under the auspices of some one of the surveys. He collected a vast number of vertebrate fossils, the descriptions and illustrations of which filled a series of large volumes.

His earliest paleontological studies were on the fossil vertebrates of the Cretaceous greensands of New Jersey. These investigations were followed by others on the Tertiary vertebrates of Maryland and North Carolina. The remains described from these fields were chiefly reptiles and marine mammals. In Ohio his discoveries were among the Carboniferous vertebrates. In Kansas he made large additions to knowledge of Cretaceous fishes and reptiles. The Eocene formations in the Bad Lands about Fort Bridger and the Green River basin yielded him many new species. From the White River beds in Colorado he obtained some seventy or more new mammals. His explorations in New Mexico, Nebraska, Montana and Oregon still increased the species, genera and families of known Mesozoic and Tertiary vertebrates; and from Texas were taken many new Permian and Carboniferous forms.

Although his interest extended over all departments of vertebrate structure, his greatest additions to knowledge were made to the Reptiles, Batrachia and Mammals. He did not confine his attention alone to fossil vertebrates. He prepared a systematic revision of the class Batrachia and was completing a similar revision of the class Reptilia at the time of his death.

For a number of years Professor Cope has been the chief editor of the "*American Naturalist*," a periodical devoted to general Natural History, and he contributed many papers discussing the philosophical problems of biology. He is, perhaps, most prominently distinguished among philosophical biologists by his ardent advocacy of the theory of consciousness as the prime factor in evolution.

His published works small and large are said to exceed 350 in number. He was a member of many scientific societies in this country and abroad; he was elected a member of the National Academy of Sciences in 1872, and at the time of his death was President of the American Association for the Advancement of Science.

MATTHEW CAREY LEA died at his residence on Sunset Avenue, Chestnut Hill, Philadelphia, on the 15th of March, 1897. He was born in 1823, and was the eldest son of Isaac Lea, the publisher, well known as a geologist and mineralogist, but especially as a conchologist, in connection with his investigations on the genus *Unio*. Mr. Lea was a member of one of the old Quaker families of Philadelphia, his ancestor John Lea who was an active member of the Society of Friends having come to this country with William Penn in 1700. Carey Lea was educated at home by private tutors and studied law in the office of the late Wm. M. Meredith, being subsequently admitted to the bar. On account of chronic ill health, however, he never practised his profession. His early associations giving him a special interest in scientific matters, he entered the laboratory of Professor James C. Booth and there acquired great proficiency in chemistry. To this science he devoted his life, his chemical researches being numerous and important, by far the greater number having been published in the pages of this Journal. He was elected to membership in the National Academy of Sciences in 1892 and the list of his more important papers then published contained fifty four titles. These investigations for the most part related to the chemistry of photography, and especially to the action of light and other forms of energy upon silver salts. He described photo-bromide and photo-iodide of silver and in 1887 published a paper on the "Identity of the photo-salts of silver with the material of the latent Photographic Image." His most remarkable discovery however, made in 1889, was that silver is capable of existing in three allotropic states. The first is allotropic silver proper, "which is protean in its nature, may be soluble or insoluble in water, may be yellow, red, blue or green or may have almost any color but in all its insoluble varieties always exhibits plasticity; that is if brushed in a pasty state upon a smooth surface its particles dry in optical contact and with brilliant metallic luster. It is chemically active." The second is intermediate in character, may be yellow or green, always shows metallic luster, is never plastic, and is chemically indifferent. The third is ordinary silver. In 1868 Carey Lea published a "Manual of Photography" which reached a second edition in 1871.

Henry Charles Lea the eminent historical writer, was a brother of Carey Lea. His first wife was a Miss Bakewell of Cincinnati who died in 1881 leaving a son, George H. Lea, who still survives. His second wife was Eva Lovering, a daughter of the late Professor Lovering of Harvard.

G. F. B.

JOSEPH F. JAMES died on the 29th day of March at Hingham, Mass. Dr. James published several papers on botanical, paleontological and geological subjects, was a fellow of the American Association for the Advancement of Science and an original fellow of the Geological Society of America.

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[FOURTH SERIES.]

ART. XLIII.—*Studies in the Cyperaceæ*; by THEO. HOLM.
IV. *Dulichium spathaceum* Pers., a morphological and anatomical study.

THE monotypic genus *Dulichium* has quite a large distribution in the eastern part of North America, extending from Nova Scotia as far south as to the tropical Florida. It is a strictly hydrophilous plant, growing socially along rivers or on borders of ponds, in wet moss or in the water itself. But in spite of the very common occurrence of our plant there are, nevertheless, some points of morphological and anatomical interest, which have, so far, escaped the attention of the botanists. Although our plant possesses only a few characters, by which it is readily distinguished from its nearest allies, a general sketch may be of some importance in order to give a more complete idea of its entire organization. It is, altogether, the writer's intention to present in these cyperographical studies a number of details, observed in the various representatives, so as to collect some data, which might facilitate the study of the mutual affinities of the genera and species of this large group of plants.

In regard to the systematic position of *Dulichium* it is generally placed near *Cyperus* and *Kyllinga* on account of the two-ranked bracts of the inflorescence; but it differs from these genera by the presence of bristles in the flower and by the distinctly beaked achenia. It is, also, generally stated that *Dulichium* has only lateral inflorescences in contrast to *Cyperus* and *Kyllinga*, but this statement is, of course, not correct, as shall be demonstrated in the present article.

If we examine the underground part of *Dulichium* we observe a rather long, horizontal rhizome with sympodial ramification and reminding one very much of *Eleocharis palus-*

tris and others. The internodes are distinct and partly covered with rudimentary, sheathing leaves. Relatively strong roots develop above the nodes, especially from the lower surface. Several stems, above-ground, arise from the rhizome and they show a structure very different from what we are accustomed to see in the *Cyperaceæ*, having numerous cylindric and hollow internodes. As we remember the stem, above-ground, of the *Cyperaceæ*, it is generally solid and forms a distinct, often very long scape. Vegetative branches do not commonly develop upon the stem, above-ground, but we have noticed, however, a few cases where a small, horizontally creeping branch had developed from the axil of one of the stem-leaves. Such secondary branches showed the same kind of ramification and structure as the rhizome.

The leaves of *Dulichium* are either reduced to tubular sheaths upon the rhizome and at the base of the stems, or they are normally developed with a linear blade, a short, crescent-shaped ligule and a long tubular sheath.

By considering the inflorescence we find the flowers arranged biserially in spikes. Each flower is perfect, supported by a scale-like bract, and has commonly eight downwardly barbed bristles, which are a little longer than the style of the ovary. The three stamens have long filaments and reach above the apex of the bristles. The style is papilliferous in its entire length like the two filiform stigmata; the achenium is at maturity oblong, flattened, shortly stipitate, and the remaining style forms a slender beak. By returning to the inflorescence, we have stated above, that the flowers are arranged in from six- to eight-flowered spikes, which again are arranged biserially along a short rhachis, which is the continuation of a short peduncle, almost entirely inclosed by the sheath of the supporting leaf. The inflorescence consists then of one terminal and about eight lateral spikes, these last being supported by scale-like bracts, but destitute of any prophylla. A prophyllon, clado-prophyllon, is, however, to be observed at the very base of the peduncle; it is very short and tubular with the apex oblique. While this general structure applies to all the lateral inflorescences of *Dulichium*, it also agrees with the terminal one, with but one exception, that no prophyllon is developed at the base of the peduncle, this being the immediate continuation of the main stem itself. By comparing now the inflorescences of our genus with those of *Cyperus*, the difference consists merely in that they are scattered along the stem in *Dulichium*, while in *Cyperus* they are gathered towards the apex of the long scape. In this way the inflorescences in *Cyperus* form like an umbel with the outer (the lowest-situated) borne on longer peduncles than the inner ones, while the terminal inflorescence is almost sessile in the center of the umbel.

The terminal inflorescence in *Dulichium* is, on the contrary, the highest situated and is readily distinguished from the lateral ones by having no prophyllon.

The most important morphological peculiarity in *Dulichium* lies, therefore, in the structure of the stem with its numerous internodes of equal length, a structure which naturally influences the composition of the inflorescence, but in reality only differing from the related genera by the non-development of one of the internodes into a scape.

We will, thereupon, examine the internal structure of our plant, beginning with the foliar organs. The cauline leaves with well-developed blade show a structure which is very much the same, as we know from the literature, to be characteristic of the genus *Carex*. The epidermis of the blade shows a very uniform structure on both faces, the upper and the lower, and it seems to be a marked characteristic of *Dulichium* that hairs are entirely wanting and that epidermal thorns very seldom occur. It is only along the margins and along the keel of the leaf that such thorn-shaped expansions are to be found. The cuticula is rather thin and stomata are only present on the lower surface of the leaf-blade; they are slightly prominent, surrounded by four cells and form generally two longitudinal rows between the mestome-bundles. Concerning the shape and the size of the individual cells, the epidermis does not show anything of interest, except that some of the cells, which lie above the median mestome-bundle, are developed as "bulliform-cells." The peculiar internal cone-shaped projections, which we have recorded in our article upon *Carex Fraseri*, abound in the epidermis of the leaves of *Dulichium*. In regard to the cell-content of the epidermis, we were rather surprised to observe that tannin was present in several of the cells, and we succeeded later on in tracing this matter to various tissues of the leaf, the stem, the rhizome and the root. Antoine Mazel* deserves the credit for being the first author who detected the tannin-reservoirs in the genus *Carex*, a fact that is the more interesting since the *Cyperaceæ* formerly, like the *Gramineæ* and the *Ranunculaceæ*, were considered exceptional in not possessing reservoirs of any kind.

The mesophyll of the leaf consists of about four strata of closely packed palissade-cells on the upper face, while the remaining part of the mesophyll is built up by more or less irregular cells, which surround large lacunes, one between each of the two mestome-bundles. By studying the development of these lacunes in very young leaves, it was observed that they originated from the coalescing of a group of from four

* Mazel Antoine: Etudes d'anatomie comparée sur les organes de végétation dans le genre *Carex*. Genève, 1891. (Reviewed by the writer in the Bot. Gazette, February, 1892.)

to five colorless cells. Very characteristic of the mesophyll are the numerous and large tannin-reservoirs of long, cylindric cells, single or several connected together. These reservoirs are especially abundant just inside the epidermis of the upper face of the leaf, where we have counted no less than fifty reservoirs inside a stratum of about one hundred epidermis-cells. They are, also, quite abundant in the inner part of the mesophyll, around the lacunes, or bordering on the parenchyma sheath of the mestome-bundles. Concerning the general distribution of the mesophyll in the leaf, it appears, on examination of transverse sections, to form isolated groups between the larger mestome-bundles, which are supported, on both faces, by groups of stereome.

The mestome-bundles are all situated in a single plane in the leaf, averaging about twenty-five on each side of the midrib; they represent two forms, according to their size. The largest are the most numerous and differ from the smaller ones by a fuller development of their leptome and hadrome; otherwise the structure is identical for both. There is a parenchyma-sheath of thin-walled and usually colorless cells, inside of which is a constantly closed mestome-sheath,* the cells of which are slightly thickened. This inner sheath, by Schwendener called the mestome-sheath, was first pointed out by this author as characteristic of the *Cyperaceæ*, *Juncaceæ* and a number of *Gramineæ*.

The leptome and the hadrome are not separated from each other by thick-walled mestome-parenchyma, and both are well differentiated in the largest bundles. The hadrome contains generally two pitted ducts and a few ring-vessels. A small lacune is often to be observed above the ring-vessels.

Stereome is not abundant in the leaf, and forms only small groups above and below the larger mestome-bundles, while the smaller bundles are merely supported by this tissue on their hadrome-side; it does not occur as isolated groups excepting in the margins of the blade. The stereome was, in some instances, observed to surround tannin-reservoirs, especially on the superior face of the leaf.

Having now examined the structure of the assimilating leaf, we might in this connection consider the bracts of the inflorescence. There are, as stated above, really two kinds of bracts in the inflorescence of *Dulichium*, viz., those which support the spikes, and those which support the single flowers, but although their shape is somewhat different their internal structure is exactly the same. These bracts show a very firm structure due to the extremely thick-walled epidermis of the dorsal face, which is the only tissue that constitutes the broad, hyaline

* Schwendener S. Die Mestomscheiden der Gramineenblätter, Sitzungsber. k. Akad., Berlin, 1890.

margins of the bracts. No stomata are to be observed and the epidermis does not show any development of the so-called bulliform-cells. Epidermal expansions as thorns were only observed along the margin, and some of the epidermis-cells of the ventral face were found to contain tannin. There are usually only five mestome-bundles, which are very weakly developed, containing merely leptome and no vessels; the mestome-sheath is well-marked and is composed of thick-walled cells. There is only a small quantity of mesophyll in the bracts, and this forms isolated groups between the mestome-bundles, being composed of a few, two or three, layers of closely packed polyedric cells. Only a few tannin-reservoirs were observed in the mesophyll.

A much stronger development is shown to be possessed by the stereome. This tissue shows, however, the same distribution as we have seen in the green leaf, but it attains a more considerable size in the bracts, where it, also, occurs in several isolated groups, viz., on both sides of the midrib and near the margins.

The stem, above-ground, is, as we have shown in the preceding cylindric, hollow and distinctly jointed. It is perfectly smooth, since the epidermis is destitute of any projections. The epidermis shows, altogether, a very uniform structure like we have seen in the leaf, and we find, also, here the internal silicious cones in those cells which cover the stereome. Stomata are present, but rather scarce, forming merely a single row between the ribs on the free part of the internodes.

The green bark, the assimilating part of the stem, does not form any closed ring in *Dulichium*. It consists of closely packed polyedric or roundish cells, and forms, in transverse sections, isolated groups between the outer band of mestome-bundles. It contains only a small number of tannin-reservoirs, which are generally situated close to the large, round lacunes. These lacunes correspond in number and arrangement to the mesophyll, which borders immediately on their exterior side. Inside the ring of lacunes is a rather heavy layer of colorless parenchyma, the cells of which are large and roundish, and in which an inner band of mestome-bundles is imbedded. The center of the internode is occupied by a wide cavity, originated from the breaking down of the central mass of fundamental tissue. The nodes themselves are solid and largely built up of very thick-walled, star-shaped cells, which are conspicuously porose.

The mestome-bundles of the stem form, as stated above, two concentric bands, those of the inner being the largest. They are all collateral, and are surrounded by thin-walled parenchyma-sheaths; the leptome and the hadrome is well differentiated and sometimes separated by a layer of thick-walled mestome-parenchyma.

Stereome is well represented in the stem, where it occurs on the leptome-side of the outer mestome-bundles and on the hadrome-side of the inner ones. In this way it does not form any closed ring neither around the single mestome-bundle nor around any of the two bands of bundles, which, otherwise, seems to be quite common in the stem of the *Cyperaceæ*.

The peduncle, the spike-bearing stem, shows very near the same structure as we have observed in the main stem. There are, however, a few differences to be found, which may be noticed here in connection with the stem-structure, since such structural divergencies between stem and peduncle have not, hitherto, been studied very much. Grevillius,* Laborie† and Trautwein‡ are some of the few authors who have treated this subject, and their studies have shown us many interesting details in regard to the anatomy of the inflorescencial axes in a number of plants.

In *Dulichium* the peduncle is strongly flattened in contrast to the cylindric stem, a fact which is due to its tight enclosure in the long leaf-sheath. It shows a relative firm structure in regard to the development of the mechanical tissue, and is solid, not hollow. The epidermis agrees very well with that of the stem, but is armed, however, with a few rows of thorn-shaped expansions along the two lateral margins. The stomata and the interior projections show the same structure and distribution as described above as characteristic of the stem. The bark-parenchyma contains chlorophyll and surrounds large lacunes, which alternate with a corresponding number of mestome-bundles.

These, the bundles, are arranged in a peripheral band; they are surrounded by a thick-walled parenchyma-sheath, and the leptome is often separated from the hadrome by mestome-parenchyma of thick-walled cells. The leptome occupies only a small part of the bundles, while the hadrome is more fully developed with several ring-vessels and generally two large pitted-ducts. The stereome forms large groups around the mestome-bundles. Tannin-reservoirs are, also, present in the peduncle, where they were observed in the bark close to the lacunes, but not in the large, colorless parenchyma, which occupies the center of the peduncle.

This is the general structure of the peduncle underneath the spike-bearing part, the rhachis, and we notice by examining this a certain change in structure, which is, especially, due

* Grevillius, A. I. Anatomiska studier öfver de florala axlarna hos diklina, Fanerogamer, Bihang Kgl. Svenska Vet. Akad. Hdlgr., vol. xvi. Stockholm 1890.

† Laborie, E. Anatomie des axes floraux. Revue scientifique, vol. xlv, Paris, 1888.

‡ Trautwein, J. Ueber Anatomie einjähriger Zweige und Blütenstandsachsen, Inaug. diss, Halle, 1885.

to the biseriate insertion of the flower-bearing spikes. A transverse section of the rhachis shows a change in regard to the outline, from almost flattened to semicylindric, while the minute structure at the same time shows some points of difference. The mestome-bundles have moved farther in towards the central, colorless fundamental tissue, and most of them have lost their outer support of stereomatic tissue. It is only on the concave side of the rhachis that the stereome is well developed so as to form supporting layers for the mestome-bundles. The mesophyll shows the same structure as in the peduncle, and it contains several lacunes of rather irregular size and shape.

Very different from the peduncle and the rhachis in regard to shape and structure is the rhacheola, the axis of the flower-bearing spike. It is broadly winged from the decurrent margins of the bracts and shows a very simple anatomical structure. The epidermis contains tannin in great abundance, and the inner tissue is largely composed of a colorless parenchyma in which two or three small mestome-bundles are imbedded. These are partly surrounded by a single layer of stereome besides by a thick-walled parenchyma-sheath; the elements of the leptome and the hadrome are well differentiated.

Having examined the aerial stem of *Dulichium* with the peduncle, the rhachis and the rhacheola, we will now proceed to the stem under-ground, the rhizome. The entire structure of the rhizome does not show any considerable strength in development, which is evidently due to the fact that the soil in which our plant grows is generally very soft and loose, and does not make any great resistance necessary. The epidermis shows naturally a much more simple structure than we observed in the stem above-ground, being deprived of stomata and epidermal projections. The cell-content is on the other hand not only represented by tannin, but also by large deposits of starch. Inside the epidermis is a broad layer of thin-walled bark-parenchyma, filled with starch, besides that tannin-reservoirs are to be seen in the outermost layers, close to the epidermis. The bark contains only one, but very large lacune, which occupies the greater part of the dorsal, the upper part of the creeping rhizome. The innermost stratum of the bark-parenchyma is differentiated into a completely closed endodermis, which, from the manner in which the cell-walls are thickened, represents a typical U-endodermis. A large, starch-bearing fundamental tissue is to be observed inside the endodermis, and it is here that the mestome-bundles are situated.

These, the mestome-bundles, are all well-developed, but are not arranged in any order; they represent two forms, viz, collateral and concentric or, in this case, perihadromatic, since

the leptome is partly surrounded by the hadrome. This form of bundle, the perihadromatic, is not uncommon in monocotyledonous plants, while the perileptomatic type is especially characteristic of the Ferns.

The mestome-bundles, the collateral and the concentric, show a still more advanced development in the rhizome than in the stem above-ground, viz., the hadrome has a greater number of pitted-ducts and the leptome-groups are much larger.

The innermost part of the central-cylinder is, as stated above, occupied by a mass of starch-bearing fundamental tissue. The stereome is rather poorly developed in the rhizome and its cells are rather thin-walled. It is here restricted to the mestome-bundles which it partly surrounds, and it seems to be strongest developed on the hadrome side, the inner face of the bundles. Numerous tannin-reservoirs were observed to be scattered around in the groups of this tissue, the stereome.

We have now pointed out the principal anatomical characteristics of the leaf and the stem with their various modifications, such as they are represented in our genus, and we might finally give a brief sketch of the root, although this was not observed to possess any peculiarities so as to be distinguished from that of the majority of the other *Cyperaceæ*. There is, inside the epidermis, a single layer of very thick-walled cells, which form a closed ring around the broad bark-parenchyma, in which a few tannin-reservoirs are to be seen. The bark shows the characteristic tangential collapsing of some of the cells, and its innermost layer is differentiated as an endodermis. The pericambium consists merely of one layer of cells, which are interrupted here and there by the protohadrome. The center of the root is occupied by two very large vessels, which alternate with the corresponding groups of leptome.

Washington, D. C., December, 1896.

EXPLANATION OF FIGURES.

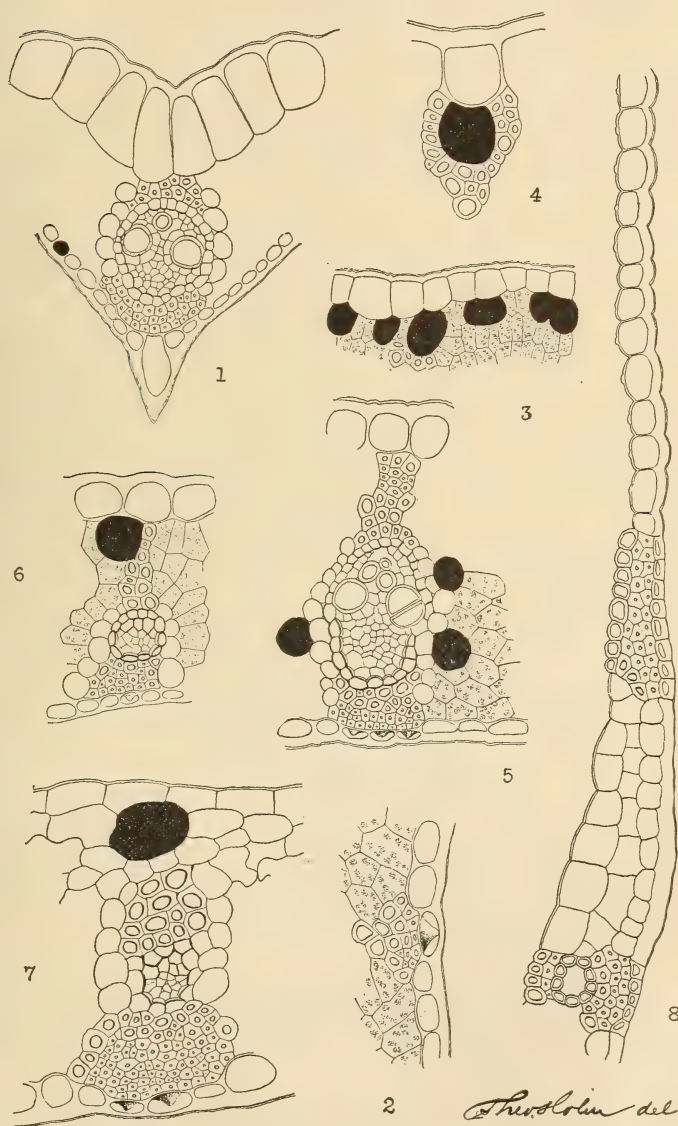
Anatomy of *Dulichium*.

- FIGURE 1.—Transverse section of the median part of the leaf-blade, showing the bulliform-cells above the median mestome-bundle. $\times 320$.
 FIGURE 2.—Transverse section of epidermis of leaf, showing a silicious cone inside one of the epidermis-cells. $\times 400$.
 FIGURE 3.—Tannin-reservoirs in the mesophyll and in the stereome from a transverse section of the leaf-blade, the upper face. The black-painted cells indicate the tannin-reservoirs in this as well as in the other figures. $\times 240$.
 FIGURE 4.—Tannin-reservoir in a group of stereome from the superior face of the leaf-blade. $\times 400$.
 FIGURE 5.—A large mestome-bundle from the leaf-blade, transverse section. Three of the epidermis-cells contain cones, and tannin-reservoirs are observable in the mesophyll. $\times 320$.

FIGURE 6.—Transverse section of a small mestome-bundle from the leaf-blade. $\times 320$.

FIGURE 7.—Transverse section of a bract, showing a mestome-bundle, a large group of stereome and a tannin-reservoir. $\times 320$.

FIGURE 8.—Same section, showing the midrib and a part of the margin, which only consists of the dorsal epidermis. $\times 60$.



ART. XLIV.—*Bacteria and the Decomposition of Rocks*; by
JOHN C. BRANNER.

HAVING had occasion recently to study certain features of rock decomposition, I was frequently told that bacteria were important agents of rock decay. I here indicate as briefly as possible the evidences considered and the conclusions reached in regard to this subject.

The *bacteriaceæ* or *schizomycetes* of the botanists are a group of the simplest microscopic fungi. Fermentation and putrefactive processes are the results of the growth of certain of these bacteria.*

The discovery that organic decay was a process of bacterial growth seems to have given rise to the idea that this decay extended to minerals and rocks as well. In 1890, Muntz, speaking of decomposed or disintegrated rocks said,† “In applying to rocks in this condition the word *decayed*, which, since the work of M. Pasteur is so clearly explained as *facts connected with the growth of microscopic organisms*, we unconsciously establish between these two orders of ideas a correlation confirmed by the researches mentioned above.” The italics are in the original. In this article Muntz speaks of having found bacteria “in the denuded rocks of the Alps, the Pyrenees, the Auvergne, and the Vosges, comprising the most varied mineralogical types: granites, porphyries, gneiss, mica schist, volcanic rocks, limestones, sandstones.† . . . Often the action of the micro-organisms is not confined to the surface, but extends into the depth of the rock mass. This is the case with the so-called *rotten* rocks of which the particles become disengaged and separate as is often seen in limestones, schists and granites. In decomposed rocks I have always verified the presence of the nitrifying organism.”

This statement of Muntz seems to have given rise to the somewhat prevalent idea that rock decay is, like organic decay, a process of bacterial growth. It appears to have been accepted without question, and one finds occasional references to the work of bacteria in rock decay as if it were a fact as well established as their work in organic decay.‡

Accepting the statement of Muntz that bacteria are found

* A. De Bary, Comparative Morphology and Biology of the Fungi, etc.; translated from the German by Garnsey and Balfour, Oxford, 1887. (Contains bibliography.) Duclaux, Chimie biologique, Paris, 1883. Cornil et Babes, Les Bacteries, 2d ed. Paris, 1886. Hueppe, Die Methoden der Bacterienforschung, Wiesbaden, 1885. Writings of Pasteur, Koch, Lankester.

† Comptes Rendus, cx, 1890, 1372.

‡ Robert Warington, U. S. Dept. of Agriculture, Exp. Sta. Bull., No. 8, p. 70; H. W. Wiley, Yearbook of the U. S. Dept. Agriculture, 1895, p. 71.

in decayed rocks, let us inquire into the possibility of their finding conditions favorable to their existence in undecayed ones.

There is a great difference among bacteria with regard to the conditions under which they thrive. For example, those called *aerobiotic* by Pasteur require a large supply of free oxygen, while the *anaerobiotic* thrive best when the oxygen is kept from them.

The kind found by Muntz in decayed rocks are what are known as nitrifying bacteria, that is bacteria that reduce nitrogenous matter to nitric acid, or nitric acid to lower forms of oxidation. To most forms organic food is absolutely indispensable, but several authorities have demonstrated that the nitrifying bacteria may live without organic food.* This fact seems at first to place the statement of Muntz beyond question, for if bacteria can live in inorganic media, why can they not live in the rocks? But these bacteria are composed principally of carbon and nitrogen and in order to live they must take up these substances with their nourishment, either from the air or from some other source. It is known that the carbon of the bacteria may be derived from organic sources. De Bary says that "as far as we fully and certainly know, the parasitic mode of life is always indispensable to the complete development of the *facultative saprophytes*," which is understood to mean that organic matter is necessary to that existence.†

Warming, a thoroughly trustworthy authority, definitely states that "*organic carbon* compounds are indispensable for all bacteria (except, as it appears, for the nitrifying organisms), as they can only obtain the necessary supplies of carbon from this source."‡ Note his exception. He also says that "the bacteria are unable to assimilate carbon from the carbonic acid of the air." Berthelot says that the carbon and hydrogen of the atmosphere does not appear to be capable of supporting the life of the nitrogen-fixing bacteria, and that they are nourished by substances furnished by higher organisms.§

Experiments by Monro in 1886,|| by Frankland in 1885-6 and by Winogradsky in 1890¶ have demonstrated that bacteria of more than one kind can be propagated in inorganic media. These media, however, of a necessity contained carbon and

* Phil. Trans. Roy. Soc., 1890, B. 107; Nature, xlv. 1892, 136-138; Annales de l'Institut Pasteur, 1890, 268; Exper. Station Bull. 8 U. S. Dept. of Agriculture, 1892, 42 et seq; Comptes Rendus, 1893, cxvi, 842-849.

† Comparative morphology and biology of the fungi, mycetozoa, and bacteria, by A. de Bary; revised by Isaac B. Balfour. Oxford, 1887, 356.

‡ A handbook of systematic botany, by Dr. E. Warming. Translated by M. C. Potter, London, 1895, 31-32.

§ Nature, May 4, 1893, xlviii, 23; Compt. Rend., 1893, 842, for April 24.

|| Jour. Chem. Soc., 1886, 651.

¶ Annales de l'Institut Pasteur, 1890, 268.

nitrogen in some available form. Frankland used a solution of ammonium chloride, potassium phosphate, magnesium sulphate, calcium chloride and calcium carbonate.* Here the carbon was supplied by the calcium carbonate and the nitrogen by the ammonium chloride (NH_4Cl). Winogradsky used ammonium carbonate, from which both nitrogen and carbon could be derived.

It is safe to assume, without demonstration, that some such source of supply of these two substances must always be at hand or else these organisms cannot live.

Leaving aside the carbon, the only known mineral sources from which nitrogen could be derived are the nitrates and nitrites and a few others, such as teschemacherite, (acid ammonium carbonate ($\text{H}\text{N}\text{H}_4\text{CO}_3$)), from guano deposits, and sal-ammoniac (ammonium chloride (NH_4Cl)), which occurs about volcanoes.† But while these minerals all occur in nature, sometimes in great quantities, as in the great niter beds of the world,‡ so far as known, they are all produced by organic agencies, and can scarcely be regarded as what geologists know as “rock-forming minerals,” that is, minerals that enter into the composition of crystalline, eruptive, metamorphic or widespread sedimentary rocks. It is true that these minerals may be carried into the soil and into the rocks by infiltration, and Mrs. Frankland points out that some forms thrive in carbonated waters.§ But even then bacteria carried in with such waters could not attack the rock-making minerals directly, but only by the formation of organic acids by their own decay. But this simply puts them back in the position of other forms of life which yield organic acids upon decomposing.

Attention is also called to the statement of Storer|| that Warington, who found “nitric ferment in loam at various depths, was no longer able to detect it with constancy and certainty at depths greater than 36 inches In none of his experiments was nitrification excited by soils taken from depths of seven and eight feet.”

Again he says “In order that nitrates may form in the soil there must be free access of air, as well as a certain amount of humidity and warmth.”

* Micro-organisms in their relation to chemical change, by Percy F. Frankland. *Nature*, xlv, 1892, 136-138.

† W. L. Watts in his “Across the Vatna Jökul,” pp. 110, 154, mentions considerable deposits of this mineral about volcanoes. Mr. Watts tells me, however, that he doubts the correctness of the determination.

‡ Stutzer and Burri are said to have found bacteria feeding on saltpeter: *Deutsch. Landw. Presse*, 1894, xxi, No. 63, p. 610.

§ Bacteria and carbonated water, by G. C. Frankland. *Nature*, August 20, 1896, 375-376.

|| Agriculture in some of its relations with chemistry, by F. H. Storer, i, 299 and 305, N. Y., 1892.

Warington also shows* that subsoil nitrification is more active during dry periods because the opening of the soil by cracks admits the air, without which it cannot take place.†

In other words nitrifying bacteria not only do not penetrate the rocks themselves to considerable depths, but they do not even penetrate the soil to a depth of more than three or four feet. In the face of this fact, and of the other fact that our granites are often decomposed to depths of more than 100 feet, it seems quite improbable if not impossible that bacteria are responsible for this deep decay or for any considerable part of it.

Prof. G. P. Merrill in his paper on the principles of rock weathering,‡ summarizes the subject well when he says of bacteria that "the depth below the surface at which such may thrive is presumably but slight, and their period of activity limited to the summer months."

It may be asked whence came the nitrates now in the soil, if not from the rocks of the earth. I do not undertake to answer this question, and only suggest that the nitrogen is contributed to largely by the nitric acid produced by electric discharges in the atmosphere, and by the union of ozone and ammonium in the air.§

It will not be out of place here to refer to other statements regarding the presence of bacteria in the rocks.

Trouessant speaks of Béchamp as holding that the organic substance of the rhizopoda of the chalk has retained its vitality in the rocks, "since a freshly cut piece, taken from the quarry with all possible precautions to exclude air-germs, is able to furnish microbes (bacteria) which multiply rapidly in a favorable medium."¶ This he is said to have demonstrated. I have not seen this statement, which is probably made in Béchamp's large work.¶ I am disposed, however, to believe that there is some mistake about this. It is difficult to believe that plants have preserved their vitality in the rocks for thousands of years. It is not difficult to believe that such forms may have been washed into cracks in the rocks, or that they may have been introduced in some of the many ways in which these organisms elude our watchfulness.

But even if there were no mistake about the matter, the existence of the original bacteria in chalk beds and the decom-

* Jour. Chem. Soc., li, 118.

† U. S. Dept. of Agriculture, Exp. Sta. Bul., No. 8, p. 70.

‡ Jour. Geol., iv, 857.

§ Bericht. deuts. Chem. Gesel., viii, 1481.

¶ Microbes, ferments, and moulds, by E. L. Trouessant, the International Sci. Ser., N. Y., 1892, p. 125, 292.

¶ Les Microzymes dans leurs rapports avec l'hétérogénie, etc.; par A. Béchamp, Paris, 1883.

position of rocks through the agency of bacteria are different questions, except in so far as the supposed bacteria of the chalk may be able to attack the surrounding materials. Trouessant also speaks of Parize finding organisms in plaster and of his belief in their power to disintegrate "schistoid rocks."*

Dr. Bernard Renault recently published a paper on the geologic work of the bacteria† in which he tells of, and reports finding bacteria in several coals.

It should also be remembered in regard to all bacteriological questions that the methods employed in such investigations are not at the command of us all alike. We are compelled to rely upon the statements of specialists, and we need to be more than ordinarily cautious in our discriminations. I am therefore disposed to look with much doubt upon the finding of bacteria in rocks by anyone else than an experienced bacteriologist. Only those who have worked at bacteriology can fully appreciate the difficulties to be encountered and the precautions to be taken in dealing with these organisms in order to prevent being misled by faulty manipulation.

* Op. cit., 123-4.

† Les bactéries et leur œuvre géologique, *Revue Générale des Sciences*, Oct. 15, 1896; abstr. *Nature*, Nov. 12, 1896, 40.

ART. XLV.—On *Wellsite*, a new Mineral; by J. H. PRATT and H. W. FOOTE.

THE mineral to be described in this article occurs at the Buck Creek (Cullakanee) corundum mine in Clay Co., North Carolina, and was collected by Professor S. L. Penfield and one of the authors (Pratt) during the summer of 1892 while engaged in work on the North Carolina Geological Survey.

The corundum vein in which the mineral is found is composed chiefly of albite, feldspar and hornblende, and penetrates a peridotite rock, dunite, near its contact with the gneiss. The peridotite outcrop is one of the largest in the State and has been thoroughly prospected for corundum. At only one of the veins opened was the new mineral found, although a careful search was made for it at all the openings, especially those affording feldspar. No mining has been done at the locality since 1891, but if work is resumed and the veins uncovered, more of the material will undoubtedly be found.

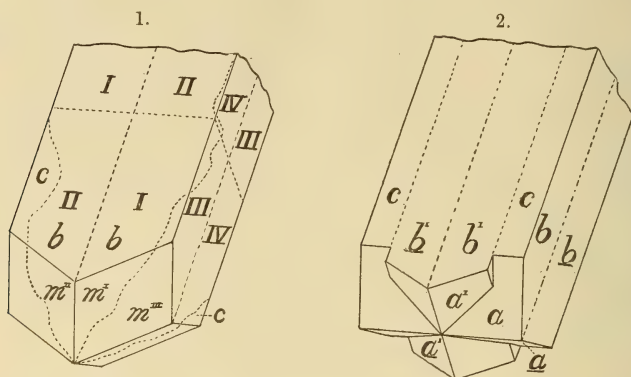
The mineral is found in isolated crystals mostly attached to the feldspar but also to hornblende and corundum, and is intimately associated with chabazite which occurs in small transparent rhombohedrons.

The largest crystals that were observed were not over 1^{mm} in diameter and 2^{mm} in length.

Crystalline form.—The crystals belong to the monoclinic system and they are twinned similarly to those of harmotome and phillipsite. The common habit is shown in fig. 1, which represents a combination of twinning about c , 001 and c , 011. The crystals are practically square prisms, terminated by pyramidal faces, thus imitating closely a simple combination of a prism of one order and a pyramid of the other in the tetragonal system. The apparent prismatic faces are formed for the most part by the pinacoid faces, b , but the crystals interpenetrate each other somewhat irregularly so that portions of the base c , 001, coincide with b , fig. 1. The lines of twinning on the pinacoid faces between b and b twinned are generally regular, while those between b and c and also those which cross the prism faces m , 110 (the apparent pyramid) are generally quite irregular. The b faces do not show the striations parallel to the edges b and m , which, meeting along the twinning lines, often reveal the complex nature of such crystals, nor were any reëntrant angles observed parallel to the edges of the apparent prism as are common on phillipsite and harmotome.

Fig. 2 represents another habit of the crystals where m , 110

is wanting and $a, 100$ is in combination with $b, 010$. The method of twinning is similar to that already described, but the crystals being terminated by $a, 100$ instead of $m, 110$ show prominent reëntrant angles at their ends. These crystals are very similar to those of harmotome from Bowling near Dumbarton on the Clyde, described by Lacroix.*



The only forms that were observed were $a, 100$; $b, 010$; $c, 001$ and $m, 110$, with $e, 011$ only as twinning plane.

The faces of the crystals are somewhat rounded and vicinal so that the reflections were not very perfect. The angle of the apparent prism $b \wedge b$ twinned is approximately 90° . Also the angle $m \wedge m$ over the twinning plane 011 could be measured only approximately, varying from $0^\circ 49'$ to $1^\circ 25'$. The approximate angles are given below, and from those marked with an asterisk the following axial ratio was calculated:

$$\alpha : \bar{b} : c = .768 : 1 : 1.245; \beta = 53^\circ 27' = 001 \wedge 100$$

| | Measured. | Calculated. |
|------------------------------------|--|----------------|
| $b \wedge \bar{b}, 010 \wedge 010$ | $*90^\circ$ (over twinning plane) | |
| $a \wedge \bar{a}, 100 \wedge 100$ | $*73 \ 6'$ (over twinning plane) | |
| $b \wedge m, 010 \wedge 110$ | $*58 \ 19$ | |
| $c \wedge a, 001 \wedge 100$ | $53 \ 27 = \beta$ | |
| $c \wedge m, 001 \wedge 110$ | $60^\circ, 59^\circ 45', 59^\circ 57'$ | $59^\circ 33'$ |

Physical properties.—The crystals are brittle and show no apparent cleavage. The luster is vitreous. Many of the crystals are colorless and transparent while others are white. The hardness is between 4 and 4.5. The specific gravity taken on a number of separate crystals, by means of the heavy solution, varied between 2.278 and 2.366. This variation was probably

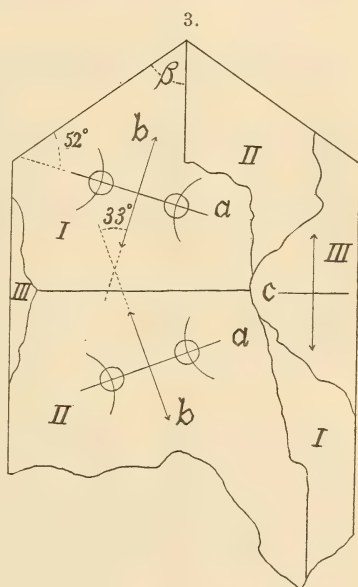
* Bull. de la Soc. Min. de France, No. 4, p. 94, 1885.

due to the difference in the ratio of the barium to the calcium in the different crystals.

A section parallel to the pinacoid faces b , 010, the apparent prism, revealed in polarized light the structure shown in fig. 3. The parts I and I extinguish simultaneously, as also II and II; while portions III, which are parallel to the basal plane, show parallel extinction. The section showed something of a zonal structure, so that the extinction could only be measured approximately. Using the Bertrand ocular, this was found to be 33° from one pinacoid on to the other over the twinning plane. The axis a makes an angle of 52° with the vertical axis c in the obtuse angle β .

The double refraction is positive and weak. The acute bisectrix c is at right angles to the pinacoid 010, and the divergence of the optical axes is large. 2E probably varies from 120° to 130° , but this could not be measured directly.

Chemical analysis. — The mineral was purified for analysis by means of the heavy solution and that which was used varied in specific gravity from 2.278 to 2.360. Water was determined by loss on ignition and silica and alumina by the ordinary methods after fusion with sodium carbonate. The filtrate from the alumina precipitation was evaporated with aqua regia to remove the large excess of ammonium salts and a small amount of ammonium chloride was again added. Calcium, barium and strontium were then precipitated together, with a considerable excess of ammonia and ammonium carbonate, and magnesia was determined in the filtrate. The mixed carbonates were dissolved in hydrochloric acid, evaporated to dryness and taken up in about 300^{cc} of water. The method used for separating barium was that recommended by Fresenius.* To the hot solution, a few drops of acetic acid were added and 10^{cc} of a 10 per cent solution of ammonium chromate containing a small amount of dichromate. After standing until the solution became cold, the clear liquid was decanted



* Zs. Anal. Chem., xxix, 426.

and the precipitate of barium chromate was washed with a weak chromate solution and with water. The precipitate was dissolved in 2^{cc} of pure dilute nitric acid, which was then partly neutralized with ammonia. Ammonium acetate was added and 10^{cc} of chromate solution as before, and after standing, the precipitate was filtered on a Gooch crucible and weighed as BaCrO₄.

The filtrate from the barium precipitation was concentrated somewhat, and calcium and the small quantity of strontium precipitated as before. They were ignited and weighed as oxide. Strontium was then separated by treatment with amyl alcohol and determined as sulphate.

The alkalies were determined by a Smith fusion in the ordinary way.

The results of the analyses are as follows:

| | I. | II. | Average. | Ratio. | |
|--------------------------------------|-------|-------|----------|--------|--------------|
| SiO ₂ | 43.62 | 44.11 | 43.86 | .731 | = 3.00 |
| Al ₂ O ₃ | 25.04 | 24.89 | 24.96 | .244 | = 1.00 |
| BaO | 5.00 | 5.15 | 5.07 | .033 | } .228 = .93 |
| SrO | 1.12 | 1.18 | 1.15 | .011 | |
| CaO | 5.76 | 5.84 | 5.80 | .104 | |
| MgO | 0.61 | 0.62 | 0.62 | .015 | |
| K ₂ O | | 3.40 | 3.40 | .036 | |
| Na ₂ O | | 1.80 | 1.80 | .029 | } = 3.04 |
| H ₂ O | 13.32 | 13.39 | 13.35 | .742 | |

100.01

The ratio of SiO₂ : Al₂O₃ : RO : H₂O is very close to 3 : 1 : 1 : 3, which gives the formula R''Al₂Si₃O₁₀ · 3H₂O. The ratio of BaO : CaO : K₂O + Na₂O in the above analyses is nearly 1 : 3 : 2 and the theoretical composition calculated for this ratio is given below together with the analysis after substituting for Na₂O its equivalent of K₂O and for MgO and SrO their equivalents respectively of CaO and BaO and then recalculating to 100 per cent.

| Theory for R''Al ₂ Si ₃ O ₁₀ · 3H ₂ O where R is $\frac{1}{2}$ Ba, $\frac{2}{3}$ Ca, $\frac{1}{3}$ K. | | |
|--|--------|--------|
| SiO ₂ | 43.12 | 42.87 |
| Al ₂ O ₃ | 24.54 | 24.27 |
| BaO | 6.65 | 6.62 |
| CaO | 6.59 | 7.27 |
| K ₂ O | 5.98 | 6.10 |
| H ₂ O | 13.12 | 12.87 |
| | 100.00 | 100.00 |

Experiments were made to determine at what temperatures the water was driven off, and the results are given in the following table, the mineral being heated in each case until the

weight became constant. The last trace of water could only be driven off by heating the mineral over the blast lamp.

| | Loss. |
|-----------------------|----------|
| At 100° C. | nothing. |
| 125 | 1.93 |
| 175 | 1.48 |
| 200 | 0.92 |
| 260 | 2.45 |
| 295 | 1.24 |
| Red heat | 4.96 |
| Over blast lamp | 0.33 |
| Total | 13.31 |

As is seen from the above, about one-third of the water, or one molecule, is given off between 100° and 200°, another third approximately between 200° and 300°, while the remainder is expelled only at an intense heat. This would indicate that the water exists in three different conditions in the molecule. If only that which is expelled below 200° be regarded as water of crystallization, the composition would be $H_4R''Al_2Si_3O_{12} + H_2O$.

That the new mineral would be closely related to the phillipsite group of the zeolites, was expected from the first on account of its crystalline form, and this relation is very satisfactorily brought out by a comparison of the crystallographic properties and chemical composition.

They all have very nearly the same axial ratios:

| | $a : \frac{b}{c} : c$ |
|-------------------|--|
| Wellsite | .768 : 1 : 1.245 $\beta = 53^\circ 27'$ |
| Phillipsite | .70949 : 1 : 1.2563 $\beta = 55^\circ 37'$ |
| Harmotome | .70315 : 1 : 1.2310 $\beta = 55^\circ 10'$ |
| Stilbite | .76227 : 1 : 1.19401 $\beta = 50^\circ 49\frac{1}{4}'$ |

In their habit and method of twinning, they are also very similar, all the crystals being uniformly penetration twins. This is especially noticeable between the new mineral and phillipsite and harmotome which are common as double twins with $c, 001$ and $c, 011$ as twinning planes.

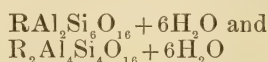
The place of the mineral in the phillipsite group is clearly shown by a comparison of their chemical compositions. Arranged in order of their proportions of silica and water to the bases, we have the following interesting series, in which R represents the bivalent elements:

| | |
|-------------------|--|
| Wellsite | $RAI_2Si_3O_{10} \cdot 3H_2O$ |
| Phillipsite | $RAI_2Si_4O_{12} \cdot 4\frac{1}{2}H_2O$ |
| Harmotome | $RAI_2Si_5O_{14} \cdot 5\frac{1}{2}H_2O$ |
| Stilbite | $RAI_2Si_6O_{16} \cdot 6H_2O$ |

The ratio of $RO : Al_2O_3$ is constant, 1 : 1, in the series, while

the proportions of silica and water have a constant ratio, 1:1, between themselves, except in the case of phillipsite. As there is, however, considerable variation in the analyses of phillipsite, it is not improbable that the ratio of $\text{SiO}_2:\text{H}_2\text{O}$, given as 4:4½, should be in some cases at least, 4:4. The minerals then form a gradual series, increasing in the proportions of SiO_2 and H_2O from wellsite to stilbite.

Fresenius* has shown that this group of minerals may be regarded as a series in which the ratio of $\text{RO}:\text{Al}_2\text{O}_3$ is constant, 1:1, while the silica and water vary between certain limits. He has assumed as these two limits:



The first would be a hydrated calcium albite and the last a hydrated anorthite. From a comparison of the wellsite-stilbite series, it seems more probable that the anorthite end would be $\text{RAl}_2\text{Si}_2\text{O}_8 + 2\text{H}_2\text{O}$, or doubling this for better comparison with the formula of Fresenius, $\text{R}_2\text{Al}_4\text{Si}_4\text{O}_{16} + 4\text{H}_2\text{O}$.

It is not unreasonable to expect that the first or anorthite member of this series may be found in nature and the completed series would then be:

| | | |
|-----------------|-------|--|
| Anorthite limit | | $\text{RAl}_2\text{Si}_2\text{O}_8 + 2\text{H}_2\text{O}$ (not yet identified) |
| Wellsite | | $\text{RAl}_2\text{Si}_7\text{O}_{10} + 3\text{H}_2\text{O}$ |
| Phillipsite | | $\text{RAl}_2\text{Si}_4\text{O}_{12} + 4\frac{1}{2}\text{H}_2\text{O}$ (perhaps $4\text{H}_2\text{O}$) |
| Harmotome | | $\text{RAl}_2\text{Si}_5\text{O}_{14} + 5\text{H}_2\text{O}$ |
| Stilbite | | $\text{RAl}_2\text{Si}_6\text{O}_{16} + 6\text{H}_2\text{O}$ |

It is also interesting to note that the formula of the new mineral wellsite is the same as that assigned to edingtonite, but the latter is essentially a barium mineral and being tetragonal shows no crystallographic relations to wellsite.

Pyrognostics.—When heated before the blowpipe, the mineral exfoliates slightly and fuses at 2.5–3 to a white bead, coloring the flame slightly yellow. In the closed tube, water is given off at a low temperature. It is very readily decomposed by hot hydrochloric acid with the separation of silica, but without gelatinization. When the water in the mineral is driven off below 265° C., it is nearly all regained on exposing the mineral to the air. If the water, however, is driven off at a red heat, none is regained by the mineral.

Name.—It is with pleasure that the authors name this mineral *wellsite* in honor of their friend Professor H. L. Wells of the Sheffield Scientific School.

In conclusion, the authors wish to express their thanks to Professor S. L. Penfield for his advice and suggestions and the kind interest he has shown during the investigation.

Mineralogical-Petrographical Laboratory,
Sheffield Scientific School, April, 1897.

* Zs. Kr., iii, 42, 1878.

ART. XLVI.—*The Magnetic Increment of Rigidity in Strong Fields*; by HOWARD D. DAY.

IN the endeavor to study the magnetic rigidity of filamentary wires in its variation with the thickness of the wire, it seemed desirable to preface the work in question by extending the experiments throughout much stronger magnetic fields than has hitherto been done. The present paper, therefore, treats of the increase of resistance to torque produced by the magnetization of twisted wires of various diameters, when the magnetic field increases to many times the amount needed to bring out the ordinary magnetic saturation.

The object of the research is to make a clear comparison between the phenomenon of magnetization or magnetic intensity on the one hand and the phenomena of magnetic rigidity on the other; to show that the two are quite distinct in character*,—that the former practically subsides in relatively weak fields, whereas the latter are not as fully complete even in the highest fields applied. It thus appears that the manifestation of magnetic saturation is but one phase of a magnetic phenomenon of a far wider range. In other words, if the magnetic qualities of iron be expressed in some way not involving direct or indirect reference to the magnetic moment, then the magnetic relations of the iron to the field will appear in quite a different light; for the influence of the increasing field on the iron will be found to continue with but slowly decreasing magnetic effects up to the limits of observation.

Work on somewhat similar lines has recently been published by Bidwell: but the Joule effect as studied by Bidwell is apparently distorted from its true nature by the occurrence of molecular rotation. The Wiedemann effect investigated in the present paper shows no apparent relation to the magnetic saturation of iron whatsoever, or, at least, is free from any contemporaneous distortion. Hence this effect is peculiarly adapted for expressing the magnetic qualities of iron throughout the wide range under which they continue with but moderately diminished sensitiveness.

The method and apparatus employed in this investigation are adaptations of that used by Barus in his researches† wherein one of two countertwisted wires similar in all respects is magnetized, and the resulting difference in rigidity of the two wires observed. The rigidity of a wire of length l and radius r , twisted by torque τ through an angle θ , is given by

$$\theta n = 2\tau l / \pi r^4$$

* Barus: this Journal, (3) vol. xxxiv, p. 181, 1887.

† Barus: Bull. U. S. Geol. Sur., No. 73, 1891.

Hence, if we look up the same torque, τ , between two counter-twisted wires of the same length, l , and radius r , θn is constant. If, therefore, θn correspond to the unmagnetic and $\theta n''$ to the magnetic wire,

$$\frac{n' - n}{n} = \frac{\theta - \theta'}{\theta'}$$

or, approximately, $\frac{\delta n}{n} = \frac{\delta \theta}{\theta}$. Thus the relative change of rigid-

ity due to magnetization is equal to the relative change of twist due to the same cause. This is, in brief, the method pursued in the following work. Apart from the inherent and unavoidable irregularities in the torsional resilience and viscosity of iron, the method unfortunately involves the fourth power of the radius. It has the advantage of a differential method, however, as well as others which appear in the following description.

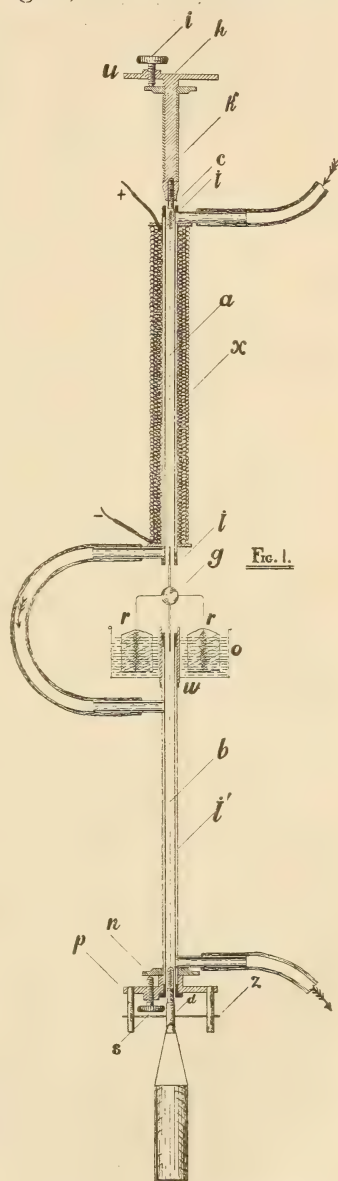
Pure iron wires were first prepared by drawing through steel plates. These wires, although not as perfect as could be desired for observations by this method, were free from all but microscopic imperfections. They were thoroughly annealed and straightened by being suspended vertically in a glass tube filled with dry hydrogen and then being heated to a cherry red by the passage of an electric current through them. In this way, bright, smooth wires free from corrosion were obtained.

A preliminary trial of the largest size of wires was made in a simple form of the apparatus used. It was then found, that, along with the effect of magnetization on the rigidity of the wire, were involved other effects upon its rigidity due to other causes. The magnetizing coil became much heated and the effect of its rise in temperature upon the rigidity of the enclosed wire was clearly apparent. A group of curves plotted from data obtained by uniting the effects of temperature and magnetization and again by separating the two, the field being kept constant, showed that the increment of rigidity due to the rise in temperature was of the opposite sign to that due to magnetization, namely, negative, and nearly proportional to the increase of temperature. This heat-effect was almost entirely removed by winding the helix about a water-jacket, through which a stream of cold water was kept constantly flowing and within which was the wire to be magnetized. Later, the other wire also was surrounded by a similar water-jacket through which the same stream of water was made to pass. The two wires were thus kept at the same uniform tem-

perature, a necessary precaution owing to the delicacy of the differential method employed. Again, variations in the tensile strain of the wires were found to produce a noticeable effect upon the data obtained. This source of error was removed by giving the lower end of the system of wires vertical freedom of motion, and suspending therefrom a small bucket of mercury, the weight of which was made proportional to the cross-sections of the wires, whenever wires of different diameters were inserted in the apparatus.

The method of observation is made clear by the section drawing of the perfected apparatus given in fig. 1. A vertical system of two iron wires have their adjoining ends soldered between two straight adjacent pieces of brass wire about 4^{cm} long. These brass wires, besides forming a rigid connection between the two iron wires, serve also to support a $\frac{1}{2}$ " circular mirror, *g*, and a pair of vanes, *r, r*, of copper foil, which are soldered to the ends of a bent cross-piece of fine brass wire, so as to hang vertically in a circular water-bath, *o*, which, by means of a central piece of tubing slips upon and is supported by the water-jacket, *j'*, which envelops the lower wire, *b*. A small spring collar, *w*, holds the bath at the proper position on the water-jacket. These vanes serve to damp the vibrations of the wires.

The upper end of the upper iron wire is soldered to a short piece of brass rod, *c*, which is made to screw tightly into the end of a vertical shaft, *h*, which is free to revolve within the sleeve, *k*. This sleeve is grasped in the jaws of a clamp, which



in turn is fastened to the upright standard supporting the whole apparatus. The shaft h is surmounted by a circular plate, u , having its outer edge graduated into degrees. This plate is pierced by a thumb-screw, i , which, by being screwed down against a flange upon the upper end of the sleeve, k , holds the shaft h at any position of its revolution within the sleeve. By this means, the system of wires is supported from the standard, and a definite amount of twist may be imparted to the system by revolving the shaft h , registered by its graduated head and maintained by clamping the thumb-screw i .

In these experiments, iron wires 25^{cm} long in the clear were used. Each wire was surrounded by a water-jacket,—the upper, by the jacket jj , the lower, by the jacket j' . These water-jackets were made by arranging concentrically two brass tubes differing in diameter by about 3^{mm}. At the ends of the tubes the spaces between them were filled by little collars. An inlet tube was inserted at the upper end of the outer tube and an outlet tube at the lower end. The whole was then made water-tight by soldering. The water-jackets were then connected in series with a source and a sink and a stream of water under pressure passed through, and thus the wire within was immersed in its field and could not have its temperature affected by that of the helix.

It has already been stated that the tensile strain upon the iron wires was regulated by suspending from the lower wire a bucket of mercury varying in weight proportionally with the cross-sections of the wires. A short piece of small brass rod, to which the lower wire was soldered, was slipped within a short sleeve of thin tubing, d , and held by a pin piercing both rod and sleeve. The bucket (an old metal cartridge) was suspended from a slanting slit in the lower end of this sleeve.

All increments of rigidity in the magnetized wire were registered as scale-deflections at the eye-piece of an observing telescope focussed upon the mirror g . In order to render unnecessary constant shifting of the telescope for focussing upon the mirror, provision was made that one-half of the twist given the wires might be imparted at the upper end in the manner already indicated, and the other half at the lower end. It is evident that the scale-image could thus be kept within the field of the telescope. This was accomplished as follows: A circular plate, p , having its outer edge graduated into degrees, was fitted to the lower end of the jacket j' , and made free to revolve upon it. This plate could be held in any position of its revolution by a thumb-screw, S , which could be screwed up against a flange, n , soldered to the water-jacket. Two short pillars, located in a diameter of the plate near its circumference, and each having a longitudinal slit lying along this diam-

eter, extended downward from the plate. These slits were engaged by a cross-wire, z , which passed through the middle of the sleeve d , and was soldered to it. It is readily seen that by this means any definite amount of twist could be imparted to the system of wires at its lower end. Moreover, the cross-wire z being free to move up and down the slits in the pillars, the tensile strain upon the wires would not be altered by the twisting process.

Provision was also made for allowing the wires to take a position of zero twist at the beginning of each experiment; for the entire lower part of the apparatus was supported on the standard already referred to by means of a clamp, which could be raised or lowered by turning a thumb-screw. To accomplish this, the lower half of the apparatus was raised by means of the screw, until the cross-wire z swung free of the slits in the pillars. The system of wires was then free to assume its position of zero twist. When they had assumed this position, the plate p was turned until the slits in the pillars were directly above the cross-wire z , when it was clamped and the apparatus lowered into its former position, the slits again engaging the cross-wire. The total twist imparted to the system would then be registered as the sum of subsequent revolutions of the plates p and u .

The helix was supported in position on the standard by wooden clamps. The standard itself was a vertical framework of brass piping embedded in a solid cast-iron base mounted on bevelling screws, the whole apparatus being located on a pier. By suspending the rubber hose connections from the standard in loops, the apparatus was rendered free from sensible jarring due to the passage of a stream of water under pressure through the water-jackets.

For regulating the strength of the current producing the field within the helix, a liquid rheostat was used. It was found, that, by the use of a rheostat where resistance coils were successively thrown into or out of the circuit, the magnetization of the wire was hindered as if by mechanical jarring. Moreover, by the use of a liquid rheostat, much finer gradations of the current could be made,—an important requisite in the carrying out of the experiments.

In this way, with a maximum E. M. F. of 165 volts, the current strength was made to vary between 0 and 15 amperes. The corresponding field-strength is obtained by substituting the constants given below for the helix in the annexed formula.

Constants of helix.

Length, 249^m.

Gauge of wire, 80 turns=7.5^{cm}.

Outside circumferences of layers of helix:—

| | | |
|-----------|-------|--------------------|
| 1st layer | ----- | ·0470 ^m |
| 2d " | ----- | ·0518 |
| 3d " | ----- | ·0569 |
| 4th " | ----- | ·0620 |
| 5th " | ----- | ·0667 |
| 6th " | ----- | ·0722 |
| 7th " | ----- | ·6767 |
| 8th " | ----- | ·0827 |

Formula for strength of field.

Mean field (in dynes) along the axis within the helix:—

$$X = \frac{\pi n I}{ab} \left\{ \sqrt{(a+b)^2 + r^2} - \sqrt{(a-b)^2 + r^2} \right\}$$

where b =distance of any point on axis of coil from center of coil.

r =radius of coil.

$2a$ =length of coil.

n =total number of turns in coil.

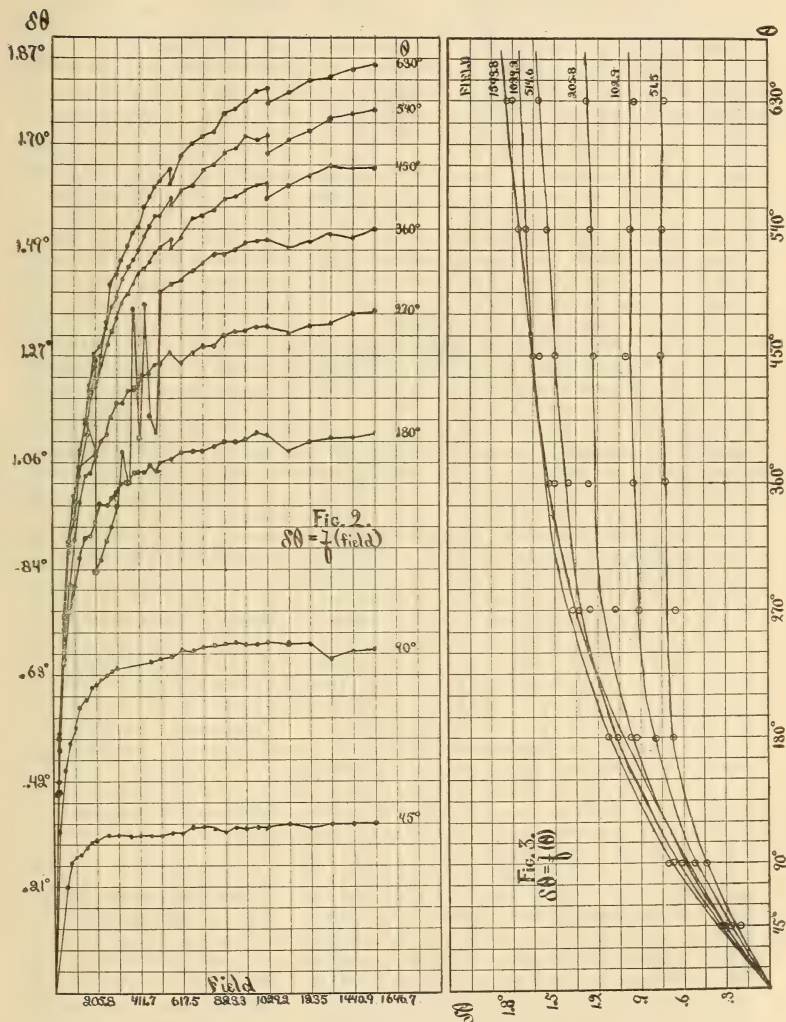
I =intensity of current in C. G. S. units.

From these constants, it is seen that the iron wire within the helix was exposed throughout its length to the magnetizing influence of fields whose mean strength along the axis of the helix reached the maximum value of 1,600 C. G. S. units.

During the course of the experiments, fresh sets of wires varying in diameter from .48^{mm} to .18^{mm} were frequently inserted in the apparatus, and the examination of the increment of rigidity was carried out in full for each set. Different amounts of twist were locked up in the countertwisted wires and at definite stages in the twisting process the upper wire was exposed to the magnetic field of the surrounding helix, which was varied in strength by successive increments of 25, 50, or 100 units from zero to the maximum value given above. For each definite value of the field-strength, the initial twist, θ , was noted and the corresponding increment of rigidity registered as a scale-deflection.

Marked effects of viscosity were in evidence throughout the experiments, and hysteresis was frequently observed. The method furnished an excellent means for observing the latter. The effects of viscosity were, however, irregular in all ways. They were most pronounced as the elastic limit of the wires was approached,—roughly, when θ equalled 4π . Viscous slip was indicated, sometimes by progressive, sometimes by jerky, scale-deflections, according as the cohesion of a few molecules

or of whole groups of them gave way at once. Upon the charts is given the number of degrees of twist, θ , registered by the index heads u and p . These can be but approximate values of the twist actually existing in the wires, for, the system being differential, only the excess of slip in one wire over



that in the other could be detected. The sign of the scale-deflections due to viscous slip was apparently accidental, yet it is to be noted that most of the slip took place in the lower—the unmagnetized—wire; this would be a natural result of an increase of the rigidity of the upper wire by magnetization.

The data obtained, when charted, show very clearly the result aimed at in the investigation. The accompanying set of

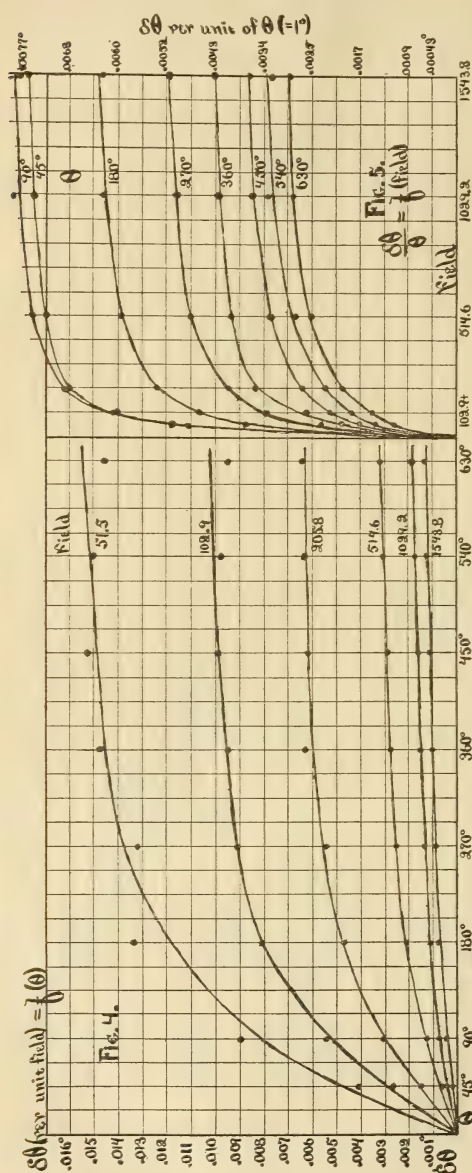


Fig. 5.
 $\frac{\delta\theta}{\theta} = f(\text{field})$

charts, obtained from the examination of a set of wires whose diameter was .294^{mm}, which is typical of the entire series, is sufficient to exhibit the results obtained. Here, $\delta\theta$, the increment of twist θ , is, as already pointed out, a very approximate relative value for the increment of rigidity, if θ be taken as the value of the initial twist. The values of $\delta\theta$ and θ are to be applied to the entire length of both wires, namely, 50^{cm}; for it is readily seen that $\delta\theta$ represents twice the actual change in the twist of either wire. Since, however, no attempt is made in this paper to give an absolute value for the increment of rigidity, the charts exhibit the true relations existing between θ , $\delta\theta$, and the field-strength.

Fig. 2 shows a family of curves in which $\delta\theta$ is a function of the field-strength. In each of these curves $\delta\theta$ is an increasing function of the field, and it is seen, that even for the largest fields used, the incre-

ment of rigidity shows no near approach to a limit; moreover,

as, in the series of curves, the initial twist, θ , becomes greater, the slope of the curves at the limit of observation also becomes greater,—showing that, with any given field, the possibility of reaching any limiting value for the increment of rigidity becomes more and more remote with the increase of θ .

The relation between the rate of change of $\delta\theta$ and the field-strength is made clearer by reference to fig. 3. These curves, plotted from the same data as those of fig. 2, show $\delta\theta$ to be an increasing function of θ . Again, as the field is increased, at the upper limit of twist the slope of the curves increases; that is, while the possibility of reaching a limiting value for $\delta\theta$ by increasing θ is remote, a concurrent increase of the field-strength renders it still more remote.

Other relations not so evident are pointed out by figs. 4 and 5, which give: fig. 4, $\delta\theta$ per unit of field as a function of θ ; fig. 5, $\delta\theta$ per unit of θ as a function of the field. They show that, while the increment of rigidity increases with the total strength of field and at the same time with the total initial torque, yet, per unit of field and per unit of initial twist, the rate of increase of the increment of rigidity diminishes and approaches the limit zero.

In proportion, then, as the field becomes stronger, the increment of rigidity varies more and more regularly with the twist, the tendency being that, in fields indefinitely large the increment of rigidity would be proportional to the twist applied.

In conclusion, in preparing this paper, acknowledgment is to be made to Dr. Barus of the University for assistance in interpreting the principles involved in the results.

Wilson Laboratory, Brown University.

ART. XLVII.—*A Geologic Fault at Jamesville, near Syracuse, N. Y.*; by PHILIP F. SCHNEIDER.

[Read before the Onondaga Academy of Science, April 30, 1897.]

IN Vanuxem's final report on the geology of the Third District of New York, page 149, we read: "Near Manlius square, two excavations were made for coal, one on the farm of Mr. Nettleton, near the turnpike, about a mile west of the village." "At this place there is a fault, the first seen upon the upper range going west."

Heretofore, local geologists have always maintained that the preceding quotation referred to a large fracture filled with calcite, which exists in the Helderberg series about a mile west of the village of Manlius, and not to a fault in the true sense of the word. While at first the question does not appear to warrant any lengthy investigation, still the fact that it is in the very midst of the horizontally stratified Paleozoic rocks of Central New York, which have recently furnished numerous evidences of igneous dikes; as at Syracuse, N. Y., at DeWitt, at Manheim, and at Ithaca; and since the location of the fault as reported by Vanuxem is right in the midst of the noted Green Lake region, which lakes have frequently been regarded as the craters of extinct volcanoes; and lastly since faults are practically unknown in this part of the state, the matter is of more than ordinary interest. This being the case, I determined to look into the matter and several visits to that locality during the past summer disclosed the following facts.

On traveling to the eastward over the turnpike from Jamesville to Manlius (Jamesville being the first station on the D. L. and W. Railroad and about seven miles south of Syracuse) the road rises almost immediately from the level plain in which the former village stands, to the top of the Helderberg escarpment, a rise of some 200 feet. After reaching the top of this escarpment the road is practically the top of the upper layer of the Corniferous limestone and for a distance of several rods is destitute of soil or earth. Half-a-mile east of Jamesville the road rises over the Marcellus shale and Goniatic limestone and for the next mile passes over this formation. Then the road drops into a small valley slightly more than a half mile in width and here is where we find the first trace of the fault. On reaching the valley at the foot of the hill, one finds a small stream crossing the turnpike and but a short distance to the west of its intersection with the direct road from Fayetteville to Pompey. At this point the stream courses over layers of the Corniferous limestone. Turning to the

right and leaving the turnpike one travels up stream to the southward. This on the farm of Mr. F. B. Fillmore. At a distance of 204 feet from the road we find ourselves at the axis of a small anticline, so slight in fact that it would be disregarded even in this region of regularly stratified rocks were it not for the fault just beyond. At a distance of 345 feet up stream we have come to an actual fault, although the layers from the direction of the turnpike are still dipping at the same slight angle to the southward.

The layers, however, which dip toward this point from the southward are those which immediately rivet our attention, in fact they could scarcely fail to attract the most casual observer. We are still in the bed of the stream, the only place where the layers are sufficiently exposed for examination. From the fault-line which is transverse to the direction of the stream, the layers rise in a sharp monocline, the cause producing the fault having bent the layers of hard Corniferous limestone so that they stand vertical at the fault-line and form as it were the arc of a great ellipse. The layers dip at a very great angle at first, then at a continually smaller and smaller angle until at a distance of 396 feet up stream from the fault we again have perfectly normal conditions. The several layers of limestone forming the west bank of the stream very distinctly show the conditions described. That there must be an actual break together with a displacement is obvious, for we have the flexed layers dipping to the north, slightly at first, then sharply, then standing vertical, met by layers of the same rock which are practically horizontal. The actual displacement appears to be about fifteen feet although this could not be accurately determined. Following up stream still farther we find no further evidences of the disturbance but simply the regular layers of Marcellus shale presently containing the seams of *Goniatite* limestone.

Although the rocks in the neighborhood of the fault are so deeply covered with drift and soil as to be wholly concealed, the topography indicates that the fault-line extends to the eastward for some distance. Further traces may be seen in the gutters on the sides of the road from Fayetteville to Pompey Hill, which is but a few rods to the east of the locality just described. These traces in the road are scarcely noticeable and no additional facts were learned from them.

By following the turnpike to the eastern side of the valley, however, we find another small stream crossing the road at a distance of 2600 feet from the first mentioned locality. This is near the house of Mr. Gifford and the stream leads back into Gifford's Glen. By turning to the right and following up stream we continually rise over the edges of layers of Cor-

niferous limestone, until at a distance of 260 yards from the turnpike we come to a comparatively level spot which is filled with the detritus of the stream, probably indicating that the top of the limestone has been reached. But from the southern end of this level stretch rises a great curved wall, as it were, of limestone. This can be noticed merely for the width of the stream. It looks just as though one layer had been stretched across the channel of the stream and then by the application of great pressure at the northern end it had been forcibly bent down some twenty or more feet there. The distance up over the inclined layers and back to the horizontal rocks again is 232 feet. The sharpest part of the bend is toward the northern end where the layers stand almost vertically. This folded layer (for only the one is visible) has been fractured in various places, showing crevasses several inches in width and extending downward a foot or more. The banks of this stream are composed either of the fissile shales of the Marcellus group, or of the dark colored soil which is the decomposed shale, as the many small pieces which it contains readily prove. Thus the layers of limestone are on a level with the shales, and a part of the limestone some 20-25 feet above the lowest part of the shales.

Beyond the southern end of the monocline we find merely the horizontal layers of shale and presently the contained layers of the Goniatite limestone with its characteristic fossils, but there are no further traces of the disturbance up stream. That the disturbance here in Gifford's Glen is identical with that mentioned by Vanuxem as existing on the Nettleton farm can hardly be doubted. The conditions are very similar, and the shales have an unusually dark color which, together with their bituminous odor, would readily suggest the existence of coal. The fault-line connecting these two most prominent disturbances would soon lead us to the eastward from Gifford's into the hillside composed of thick Marcellus shales, and as there are no streams in this direction which have worn through the shales to the underlying limestone, the fault could not be traced beyond this point. As the greatest amount of displacement observed exists at Gifford's Glen, it would seem that the fault exists for a considerable distance to the eastward from that point. That it must extend for some distance to the west of Fillmore's is also evident. The fault-line connecting these two disturbances lies 20° north of east; the localities are nearly a half mile apart.

Further observations along this parallel may result in bringing other traces of the fault to light, but this is not probable. Special interest and importance attaches to this subject at this time, because it gives to us another disturbance in this region where until recently such disturbances were not supposed to exist.

ART. XLVIII.—*On Certain Double Halogen Salts of Cæsium and Rubidium*; by H. L. WELLS and H. W. FOOTE.1. *The Complicated Rubidium-Antimony Chloride.*

REMSEN and SAUNDERS* have described a salt to which they gave the formula $23\text{RbCl} \cdot 10\text{SbCl}_3$ as the most probable one. Wheeler,† working in this laboratory, confirmed Remsen and Saunders' results and discovered besides an analogous bromide, to which the probable formula $23\text{RbBr} \cdot 10\text{SbBr}_3$ was given. Remsen and Brigham‡ prepared the salt $23\text{RbCl} \cdot 10\text{BiCl}_3$. Herty§ has since described the two potassium salts $23\text{KCl} \cdot 10\text{SbCl}_3$ and $23\text{KBr} \cdot 10\text{SbBr}_3 \cdot 27\text{H}_2\text{O}$, and some mixtures of these two salts.

In view of all this work, there can scarcely be a doubt as to the existence of a type of salts with a somewhat complicated ratio, but in view of the fact that this complicated ratio 23 : 10 is apparently an exception to the simplicity of composition of all other carefully investigated double halogen salts, the subject seemed worthy of some further investigation. For the purpose, we have studied only the rubidium-antimony chloride of Remsen and Saunders, as this salt is readily prepared and is capable of repeated recrystallization from hydrochloric acid solution.

The possibility suggested itself that the product might consist of two simpler salts of similar or identical crystalline form, which were capable of crystallizing together, and that previous investigators had made use of conditions which resulted in obtaining a constant mixture of two such salts. Although this supposition had scarcely any probability in view of the existence also of the rubidium-antimony bromide and of the two potassium salts, we have put the question to test by repeatedly recrystallizing the salt, using not only ordinary dilute hydrochloric acid for this purpose, but also more dilute and much more concentrated acid and also an alcoholic hydrochloric acid solution. As will be seen from the analyses, given beyond, no variation in composition could be detected by the use of these widely varying solvents for recrystallization, and it therefore appears impossible that the salt can be a mixture.

As a starting point, we used a solution in hydrochloric acid containing the constituents RbCl and SbCl_3 in the exact molecular proportion 23 : 10. Product A was the first, B the third and C the fifth recrystallization from pure dilute hydrochloric acid. The product D was obtained by adding concentrated

* Am. Chem. Jour., xiv, 155.

† This Journal, xlvi, 269.

‡ Am. Chem. Jour., xiv, 174.

§ Am. Chem. Jour., xvi, 490.

hydrochloric acid to a nearly saturated warm solution of the salt in dilute hydrochloric acid. E was obtained from a very strong hydrochloric acid solution formed by passing a rapid current of hydrogen chloride gas into the solution as it cooled. F was obtained by recrystallizing the salt from hydrochloric acid which was kept as dilute as it could be without producing the basic double salt to be described beyond. G was a product obtained by recrystallizing the salt from a mixture of equal volumes of dilute hydrochloric acid and alcohol.

The two products obtained from concentrated hydrochloric acid solution had a pale yellow color while the others were all white. The crystals were usually well-formed six-sided plates which showed no definite optical properties.

The analyses of the various products are as follows:

| | Rubidium. | Antimony. | Chlorine. |
|---------------|-----------|-----------|-----------|
| A ----- | 39.23 | 23.85 | 37.01 |
| B ----- | 39.23 | 23.84 | 36.99 |
| C ----- | | 23.91 | ---- |
| D ----- | 39.25 | 23.98 | ---- |
| E ----- | 39.31 | 23.89 | ---- |
| F ----- | 39.03 | 23.86 | ---- |
| G ----- | 39.11 | 23.90 | ---- |
| Average ----- | 39.19 | 23.89 | 37.00 |

Method of analysis.—For the determination of antimony and rubidium, a portion of about one-half a gram was dissolved in water and enough hydrochloric acid to prevent antimony oxychloride from precipitating. The solution was heated to boiling and hydrogen sulphide passed in. The solution was then cooled and the antimony sulphide filtered on a Gooch crucible and washed with water and with alcohol. The crucible was then slowly heated to 230° and cooled in an oven filled with carbonic acid. The precipitate was weighed as Sb_2S_3 . The filtrate containing rubidium was evaporated with sulphuric acid and the residue ignited in a stream of air containing ammonia and weighed as Rb_2SO_4 . Chlorine was determined by dissolving a separate portion in water acidified with tartaric and nitric acids and precipitating with silver nitrate. This was allowed to stand for some time and the precipitate was then collected on a Gooch crucible and weighed. The methods used are almost identical with those of Wheeler.

The accuracy of the antimony determination was checked in the following manner. The salt $\text{Cs}_3\text{Sb}_2\text{Cl}_6$ was prepared from very pure materials and carefully recrystallized and antimony determined by the above method. The per cent of antimony is nearly the same as in the rubidium antimony salt under consideration. The following results were obtained:

| | I. | II. | III. | IV. |
|---------------------------|-------|-------|-------|-------|
| Per cent Sb found | 25·37 | 25·42 | 25·43 | 25·44 |
| “ “ calculated | 25·13 | — | — | — |

The atomic weights used in all the calculations were Rb 85·43; Sb 120·43; Cl 35·45; S 32·07; Ag 107·92; Cs 132·89.

Since the method used for the determination of antimony gives results which are slightly too high, we believe that a deduction of the average error 0·25 per cent from the antimony found in the analyses of the rubidium salt will give a result which is nearer the truth.

| | Rb. | Sb. | Cl. |
|---|-------|-------|-------|
| Average previously given | 39·19 | 23·89 | 37·00 |
| Average with correction for Sb | 39·19 | 23·64 | 37·00 |
| Calculated for $\text{Rb}_{23}\text{Sb}_{10}\text{Cl}_{53}$ | 38·92 | 23·86 | 37·22 |
| Calculated for $\text{Rb}_7\text{Sb}_3\text{Cl}_{16}$ | 39·18 | 23·66 | 37·16 |

It may be noticed that the results agree rather more satisfactorily with the formula $7\text{RbCl} \cdot 3\text{SbCl}_3$ than with the more complicated one advanced by Remsen and Saunders. The differences between these formulæ are, however, so slight that it is probably entirely impossible to decide between them by means of chemical analysis, the ratio Rb:Sb being 230:100 in one case, and in the other 233:100. However, since it is customary to use the simplest applicable formula for a chemical compound, we propose the formula $7\text{RbCl} \cdot 3\text{SbCl}_3$ for this salt and corresponding formulæ for other salts of this series. Herty's hydrous salt, to which he gave the formula $23\text{KBr} \cdot 10\text{SbBr}_3 \cdot 27\text{H}_2\text{O}$, agrees well with the formula $7\text{KBr} \cdot 3\text{SbBr}_3 \cdot 8\text{H}_2\text{O}$. It must be admitted that the 7:3 ratio is an unusually complicated one, but it is far simpler than 23:10 and is scarcely a marked exception to the general simplicity of double halogen salts.

2. A rubidium-antimony oxychloride, $2\text{RbCl} \cdot \text{SbCl}_3 \cdot \text{SbOCl}$.

In attempting to recrystallize the salt $7\text{RbCl} \cdot 3\text{SbCl}_3$ from very dilute hydrochloric acid, just enough to prevent the formation of antimony oxychloride, this new salt was obtained in the form of short colorless prisms possessing a rather high luster. It can be recrystallized from very dilute hydrochloric acid.

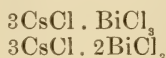
The following results were obtained from analyses of separate crops:

| | I. | II. | Calculated for $2\text{RbCl} \cdot \text{SbCl}_3 \cdot \text{SbOCl}$. |
|------------------------|-------|-------|---|
| Rb | 26·54 | 26·68 | 26·68 |
| Sb | 37·58 | 37·36 | 37·61 |
| Cl | 32·75 | 32·80 | 33·21 |
| O (by diff.) | 3·13 | 3·16 | 2·50 |

It is interesting to notice that Benedict* has described the potassium salt $2KCl \cdot SbCl_3 \cdot SbOCl$, which corresponds exactly to this rubidium compound.

3. The Cesium-Bismuth Chlorides and Iodides

The double chlorides of bismuth with cesium have been described by Remsen and Brigham.† These authors did not state, however, how widely the conditions had been varied, and we have repeated the work, varying the proportions of cesium and bismuth as much as possible, and have found exactly the same salts as described by them. These salts are,



3CsCl. BiCl₃.—This salt forms in colorless plates when 50% of cesium chloride are mixed in hydrochloric acid solution with from 1–25% of bismuth chloride. The analyses were made on samples, dried but a short time in the air, which apparently contained a little mechanically included water. The following results were obtained:

| | I. | II. | Calculated for 3CsCl. BiCl ₃ . |
|----------|-------|-------|--|
| Bi | 24.80 | 24.47 | 25.36 |
| Cs | 47.94 | ---- | 48.66 |
| Cl | ---- | ---- | 25.98 |

3CsCl. 2BiCl₃.—When 50% of bismuth chloride are mixed with from 1–80% of cesium chloride, the salt $3CsCl \cdot 2BiCl_3$ crystallizes in light yellow needles, sometimes broadened and looking like plates and again much shorter and thicker.

The following analyses were made:

| | I. | II. | Calculated for 3CsCl. 2BiCl ₃ . |
|----------|-------|-------|---|
| Bi | 36.99 | 36.58 | 36.67 |
| Cs | 34.69 | 34.94 | 35.17 |
| Cl | ---- | ---- | 28.16 |

3CsI. 2BiI₃. Cesium-Bismuth Iodide.

We could obtain only one double iodide of bismuth and cesium, although the proportions of cesium and bismuth were varied greatly. The salt formed as a crystalline precipitate, difficultly soluble especially in an excess of cesium iodide, when 1% of bismuth iodide was added to 50% of cesium iodide and when 1% of cesium iodide was added to 50% of bismuth iodide. With an excess of cesium, the color was a bright red,

* Proc. Am. Acad., xxix, 212.

† Amer. Chem. Jour., xiv, 179.

while with an excess of bismuth the color was more of a red-dish brown.

Methods of Analysis.—The methods here given were used in both the double chlorides and iodide of bismuth.

Halogens were determined as the silver salts being precipitated from a solution acidified with tartaric and nitric acids and, after standing, filtered and weighed on a Gooch crucible. As Remsen and Brigham had mentioned a difficulty in determining bismuth, we made a few determinations of it in Bi_2O_3 , which was made by precipitating BiONO_3 with water from a nitric acid solution of $\text{Bi}(\text{NO}_3)_3$, and heating the precipitate to constant weight in a platinum dish. The method finally adopted was to dissolve the substance in water slightly acidified with hydrochloric acid and precipitate Bi_2S_3 from the cold solution with hydrogen sulphide. The precipitate was filtered and immediately dissolved in nitric acid and digested for some time on the water bath until completely decomposed. The sulphur was filtered off and the filtrate, diluted to about 300–400^{cc}, was heated and ammonium carbonate added in slight excess. It was placed on the water bath for an hour or two, until the liquid had become nearly clear and the excess of ammonium carbonate had been driven off, and it was then filtered on a Gooch crucible and ignited strongly over a Bunsen burner and weighed as Bi_2O_3 .

Two determinations on Bi_2O_3 gave the following results:

| | | |
|----|--|--|
| I | Amt. Bi_2O_3 taken = 0.1979 ^g | Amt. Bi_2O_3 found = 0.1974 ^g |
| II | “ “ “ = 0.3604 | “ “ “ = 0.3617 |

The filtrate from the bismuth precipitation was evaporated with sulphuric acid and ignited in a stream of air containing ammonia. The residue was weighed as Cs_2SO_4 .

The results obtained from the analysis of the double iodide were as follows:

| | I. | II, | Calculated for $\text{Cs}_3\text{Bi}_2\text{I}_9$. |
|----------|-------|-------|--|
| Bi | 21.34 | 21.15 | 21.25 |
| Cs | 20.75 | 20.31 | 20.38 |
| I | ---- | 58.02 | 58.37 |

Sheffield Chemical Laboratory, New Haven, January, 1897.

ART. XLIX.—*On the Double Fluorides of Zirconium with Lithium, Sodium and Thallium*; by H. L. WELLS and H. W. FOOTE.

In a previous article* we have described the cæsium-zirconium fluorides, and upon comparing these with the corresponding ammonium and potassium salts, which had been previously described by Marignac† it was observed that the types of salts formed varied with the molecular weights of the alkaline fluorides in an interesting manner. The fluorides of smaller molecular weight gave types with a larger relative number of these molecules, while the fluorides of higher molecular weights combined with more zirconium fluoride than the others. This relation is made clear from the following table, which was given in the previous article referred to:

| 3 : 1 Type. | 2 : 1 Type. | 1 : 1 Type. | 2 : 3 Type. |
|---|---|---------------------------------|---|
| $3\text{NH}_4\text{F} \cdot \text{ZrF}_4$ | $2\text{NH}_4\text{F} \cdot \text{ZrF}_4$ | ----- | ----- |
| $3\text{KF} \cdot \text{ZrF}_4$ | $2\text{KF} \cdot \text{ZrF}_4$ | $\text{KF} \cdot \text{ZrF}_4$ | ----- |
| ----- | $2\text{CsF} \cdot \text{ZrF}_4$ | $\text{CsF} \cdot \text{ZrF}_4$ | $2\text{CsF} \cdot 3\text{ZrF}_4 \cdot 2\text{H}_2\text{O}$ |

The present investigation was undertaken with the view, in the first place, of testing the apparent rule with lithium fluoride, which has a lower molecular weight than the fluorides previously experimented upon. Our expectations were realized by the preparation of the salt $4\text{LiF} \cdot \text{ZrF}_4 \cdot \frac{2}{3}\text{H}_2\text{O}$. The salt $2\text{LiF} \cdot \text{ZrF}_4$ was also obtained, but, in spite of a careful search, no intermediate 3:1 salt could be discovered. The following table, giving the lithium, potassium and cæsium salts, shows a perfectly symmetrical gradation in types according to the atomic weights of the alkali metals, except that the intermediate lithium salt is missing.

| Type. | Lithium salts. | Potassium salts. (Marignac.) | Cæsium salts. |
|-------|--|---|---|
| 4 : 1 | $4\text{LiF} \cdot \text{ZrF}_4 \cdot \frac{2}{3}\text{H}_2\text{O}$ | ----- | ----- |
| 3 : 1 | ----- | $3\text{KF} \cdot \text{ZrF}_4$ | ----- |
| 2 : 1 | $2\text{LiF} \cdot \text{ZrF}_4$ | $2\text{KF} \cdot \text{ZrF}_4$ | $2\text{CsF} \cdot \text{ZrF}_4$ |
| 1 : 1 | ----- | $\text{KF} \cdot \text{ZrF}_4 \cdot \text{H}_2\text{O}$ | $\text{CsF} \cdot \text{ZrF}_4 \cdot \text{H}_2\text{O}$ |
| 2 : 3 | ----- | ----- | $2\text{CsF} \cdot 3\text{ZrF}_4 \cdot 2\text{H}_2\text{O}$ |

Marignac's two ammonium salts, 3:1 and 2:1, also enter the series symmetrically.

We have investigated also the thallous-zirconium fluorides, since the high atomic weight of thallium led us to expect that it would possibly yield a series of salts symmetrical with those

* This Journal, IV, i, 18.

† Ann. Chim. Phys., ix, 257.

of the alkali metals with a still higher ratio of zirconium than was the case with caesium. Such was not the case, however. The salts discovered were :

$3\text{TlF} \cdot \text{ZrF}_4$, $5\text{TlF} \cdot 3\text{ZrF}_4 \cdot \text{H}_2\text{O}$, $\text{TlF} \cdot \text{ZrF}_4$ and $\text{TlF} \cdot \text{ZrF}_4 \cdot \text{H}_2\text{O}$.

Two of these three types of thalious salts correspond to types of alkali-metal salts, while one type, the 5 : 3, is a new one, but the series is not symmetrical with the others according to the atomic weights.

Since Marignac had described but one sodium-zirconium fluoride, $5\text{NaF} \cdot 2\text{ZrF}_4$, and since this differs from all other alkaline zirconium fluorides, we have undertaken a new investigation of the sodium salts. As a result, we have fully confirmed Marignac's results as to the 5 : 2 salt, which is the one most readily obtained, and we have succeeded in preparing a new salt, $2\text{NaF} \cdot \text{ZrF}_4$, which corresponds to the most usual type of double halogen salts of tetravalent elements. It is evident, however, that the sodium salts, like those of thallium, do not form a symmetrical series with the others.

The following table gives a list of the sodium and thallium salts and shows the positions, "X" of the other compounds prepared by Marignac and ourselves.

| Type. | Lithium salts. | Ammonium salts. (Marignac) | Sodium salts. | Potassium salts. (Marignac.) | Cæsium salts. | Thallium salts. |
|-------|----------------|-------------------------------|-----------------------------------|---------------------------------|---------------|--|
| 4 : 1 | X | ----- | ----- | --- | --- | ----- |
| 3 : 1 | -- | X | ----- | X | --- | $3\text{TlF} \cdot \text{ZrF}_4$ |
| 5 : 2 | -- | -- | $5\text{NaF} \cdot 2\text{ZrF}_4$ | --- | --- | ----- |
| 2 : 1 | X | X | $2\text{NaF} \cdot \text{ZrF}_4$ | X | X | ----- |
| 5 : 3 | -- | -- | ----- | --- | --- | $5\text{TlF} \cdot 3\text{ZrF}_4 \cdot \text{H}_2\text{O}$ |
| 1 : 1 | -- | -- | ----- | X | X | $\left\{ \begin{array}{l} \text{TlF} \cdot \text{ZrF}_4 \\ \text{TlF} \cdot \text{ZrF}_4 \cdot \text{H}_2\text{O} \end{array} \right.$ |
| 2 : 3 | -- | -- | ----- | --- | X | ----- |

While our investigation has shown that the rule for the variation of the types with the atomic weights applies only partially to the zirconium double fluorides, we have shown at least that the variety of types is remarkable and it is also noticeable that the ratios are nearly the simplest that can exist in such number between the extreme limits 4 : 1 and 2 : 3.

Preparation.—Thallium fluoride was prepared by dissolving the metal in sulphuric acid, adding an excess of baryta water, filtering and passing carbonic acid into the hot solution. The filtrate from this precipitation was evaporated and treated with hydrofluoric acid in excess. The salts were prepared by mixing the acid solutions of the fluorides in varying proportions, evaporating and cooling to crystallization. The salts were

then removed and pressed between filter papers till dry. In all cases, they were stable in the air.

Method of analysis.—Zirconium and the alkalies were determined by evaporating the salt with sulphuric acid to drive off hydrofluoric acid, precipitating zirconium hydroxide with ammonia and weighing ZrO_2 . The filtrate was evaporated to dryness and the alkali determined as sulphate, either by igniting with ammonium carbonate or heating in a current of air containing ammonia. When thallium was present, the fluoride was dissolved in water, a little sulphurous acid added to make sure that the thallium was all in the univalent condition, and the zirconium precipitated with ammonia. The precipitate needed to be very thoroughly washed. The filtrate was evaporated nearly or quite to dryness to remove free ammonia, diluted to a volume of about 100 cc, heated to boiling and potassium iodide added in excess to precipitate thallium iodide. This was collected on a Gooch crucible, washed with eighty per cent alcohol, dried at 100° C. and weighed. Fluorine was determined by the ordinary calcium fluoride method after precipitating zirconium with ammonia and removing ammonium salts by evaporation with sodium carbonate. Water was determined by heating the salt in a combustion tube behind a layer of dry sodium carbonate and collecting the water in a calcium chloride tube.

Salts of Lithium.

$2\text{LiF} \cdot \text{ZrF}_4$.—This salt forms when from 0.7^g to 2^g of lithium fluoride are added to 20^g of zirconium fluoride. The crystals are hexagonal, showing prism and pyramid and rarely a basal plane. In appearance, they are very much like crystals of quartz from Herkimer Co., N. Y., but they are very small. On recrystallizing, the 4 : 1 salt was formed.

Separate crops were analyzed with the following results :

| | I. | II. | Calculated for Li_2ZrF_6 . |
|----------|-------|-------|---|
| Li | 6.03 | 6.39 | 6.42 |
| Zr | 41.81 | 41.64 | 41.28 |
| F | | 51.62 | 52.30 |

$4\text{LiF} \cdot \text{ZrF}_4 \cdot \frac{2}{3}\text{H}_2\text{O}$.—This was the most unsatisfactory salt obtained, though it seems undoubtedly to establish the 4 : 1 type. As lithium fluoride is very insoluble, only a comparatively small amount could be dissolved in zirconium fluoride and apparently we could not go far enough toward the lithium end to get the salt in pure condition. It formed in a crust ordinarily and the crystals were very small. Under the microscope, no mixture with another salt could be found in the

crops analyzed. Once, however, it was obtained mixed with the 2:1 salt, as seen under the microscope, showing there could probably be no intermediate salt. Various conditions were tried and crops were obtained from both hot and cold solutions. It forms when 5 to 7% of lithium fluoride are mixed with 20% of zirconium fluoride. On recrystallizing, lithium fluoride is precipitated.

Following are the results of the analyses:

| | Li. | Zr. | H ₂ O. | F. |
|---|-------|-------|-------------------|-------|
| I | 9.54 | 33.14 | 4.83 | ---- |
| II | ----- | ----- | 4.93 | ----- |
| III | 9.79 | 33.30 | 4.35 | 53.16 |
| IV | ----- | 33.23 | ----- | ----- |
| V | ----- | 33.02 | ----- | ----- |
| Calculated for Li ₄ ZrF ₈ · $\frac{2}{3}$ H ₂ O .. | 9.93 | 31.91 | 4.26 | 53.90 |

Salts of Sodium.

2NaF. ZrF₄.—This salt crystallizes in very minute crystals of hexagonal outline, coming down in a crust when from one to two parts of sodium fluoride are added to fourteen parts of zirconium fluoride. The salt does not recrystallize. The following results were obtained from separate crops. The water was probably mechanically included.

| | I. | II. | Calculated for Na ₂ ZrF ₆ . |
|------------------------|-------|-------|--|
| Na | 18.66 | 18.41 | 18.40 |
| Zr | 34.78 | 36.21 | 36.00 |
| H ₂ O | 1.96 | 0.50 | ----- |
| F* | 44.60 | 44.88 | 45.60 |

5NaF. 2ZrF₄.—Marignac has previously described this salt, which comes down under wide conditions in very good crystals and recrystallizes easily. Prof. L. V. Pirsson has kindly examined the crystals and made the following report:

"The crystals show good sharp forms but are very small. They appear distinctly orthorhombic in habit, consisting in the main of rather stout prisms, made up of two prismatic planes, *m* and *m'* and terminated by a rather steep brachydome. In another habit, which is rarer, the front pinacoid, *a*, is broadly developed while the prisms are very small; this type also shows at times a pyramid, *p*. The plane of the optic axes lies in the base and *a* = *c*, *b* = *a*, *c* = *b*. The optic angle is large and it could not be told whether *a* or *b* was the acute bisectrix. The double refraction is very low. The crystals in their form strongly recall the figures of chrysolite (olivine) shown in the mineralogies."

* By difference.

The analyses gave the following results from different crops:

| | I. | II. | Calculated for $\text{Na}_2\text{Zr}_2\text{F}_{13}$. |
|----------|-------|-------|---|
| Na | 21.15 | 21.09 | 21.23 |
| Zr | 33.63 | 33.55 | 33.22 |
| F* | 45.22 | 45.36 | 45.57 |

Salts of Thallium.

$\text{TlF} \cdot \text{ZrF}_4 \cdot \text{H}_2\text{O}$ and $\text{TlF} \cdot \text{ZrF}_4$.—These salts crystallize in somewhat concentrated solutions when one part of thallium fluoride is mixed with three or four parts of zirconium fluoride. The analyses invariably show an excess of zirconium fluoride. The hydrous salt crystallizes in needles, if the solution be cooled before precipitation occurs. If the solution is evaporated until crystals begin to form and then cooled, the anhydrous salt deposits in minute square plates. The salt gives the 5:3 type on recrystallizing. The following results were obtained:

| | I. | II. | Calculated for $\text{TlZrF}_5 \cdot \text{H}_2\text{O}$. |
|----------------------------|-------|-------|---|
| Tl | 48.43 | 47.91 | 50.05 |
| Zr | 22.93 | 23.16 | 22.15 |
| F | — | 23.17 | 23.37 |
| H_2O | 3.89 | 4.80 | 4.43 |

| | | | Calculated for TlZrF_5 . |
|----------|-------|-------|--------------------------------------|
| Tl | 50.16 | 49.91 | 52.37 |
| Zr | 23.86 | 24.08 | 23.17 |
| F | — | 24.32 | 24.46 |

$5\text{TlF} \cdot 3\text{ZrF}_4 \cdot \text{H}_2\text{O}$.—This salt crystallizes in needles when from one to three and one-half parts of thallium fluoride are added to one part of zirconium fluoride. When about four parts of thallium fluoride are added, the same salt crystallizes in a different habit, forming prisms of hexagonal outline which under the microscope are seen to be twinned, resembling in this respect the hexagonal-shaped crystals of aragonite. On recrystallizing, both habits give the needle-shaped crystals.

The following analyses were made of the two kinds of crystals. A rather large number of determinations was made on account of the existence of two different forms.

* By difference.

| | Tl. | Zr. | H ₂ O. | F. |
|---|-------|-------|-------------------|-------|
| I..... | 61·58 | 16·88 | ---- | ---- |
| II..... | 62·05 | 16·84 | ---- | ---- |
| III..... | 61·37 | 17·14 | 1·40 | ---- |
| IV..... | 61·58 | 16·88 | 1·17 | 19·31 |
| V..... | 61·74 | 17·04 | 1·42 | ---- |
| VI..... | ---- | ---- | 1·31 | ---- |
| VII..... | 62·91 | 16·42 | ---- | ---- |
| Calculated for $Tl_5Zr_3F_{17} \cdot H_2O$.. | 62·47 | 16·58 | 1·11 | 19·84 |

3TlF. ZrF₄.—Crystals of this salt form in brilliant octahedra when one part of zirconium fluoride is added to from four to twenty parts of thallium fluoride. It is easily recrystallized.

The following analyses were made :

| | I. | II. | Calculated for Tl_5ZrF_{17} . |
|---------|-------|-------|------------------------------------|
| Tl..... | 72·82 | 73·20 | 73·24 |
| Zr..... | 10·91 | 10·38 | 10·80 |
| F..... | 15·65 | ---- | 15·96 |

Sheffield Chemical Laboratory, New Haven, January, 1897.

ART. L.—*Preliminary Note on the Broadening of the Sodium Lines by Intense Magnetic Fields*; by A. STC. DUNSTAN, M. E. RICE and C. A. KRAUS.

DR. P. ZEEMAN (Phil. Mag., March, 1897), using as a source of light a Bunsen flame between the poles of an electromagnet, has shown that the sodium lines are broadened by the influence of an intense magnetic field. To obtain the necessary dispersion he used a large concave grating.

It occurred to the writers that the interferometer invented by Michelson of Chicago University, being far more powerful than a grating for the purpose of analyzing a single line in the spectrum, ought to show the effect of magnetic influence more decidedly.

For this purpose the apparatus was arranged as shown in

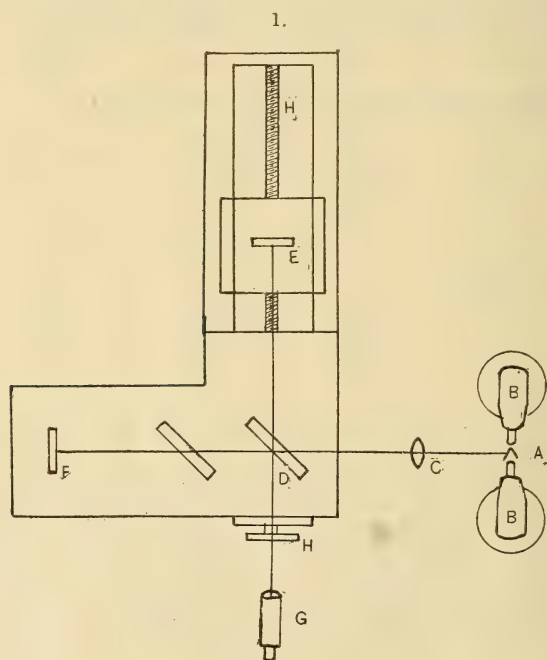


fig. 1. The light was furnished by a Bunsen flame A, placed between the poles of a powerful electromagnet B.

A piece of asbestos saturated with NaOH solution was wrapped around the burner at the top. The light is rendered slightly convergent by the lens C and falls upon the semi-

silvered surface D, where part is reflected to the movable mirror E and part transmitted to the fixed mirror F. These two beams are reflected and both finally enter the telescope G.

Under these conditions, with a telescope focussed for parallel rays or with the unaided eye, the observer will see a series of concentric circular fringes. If now the mirror E is moved away from the observer by turning the screw H, the difference of path of the interfering pencils is increased and the fringes become periodically more or less distinct or "visible," passing through successive maxima and minima.

The visibility is defined as the ratio between the difference of intensities of a bright and a dark ring divided by the sum of these intensities, or expressed algebraically,

$$V = \frac{I_{\text{bright}} - I_{\text{dark}}}{I_{\text{bright}} + I_{\text{dark}}}$$

If now the visibilities at the maxima be observed for increasing differences of path, then the approximate equation

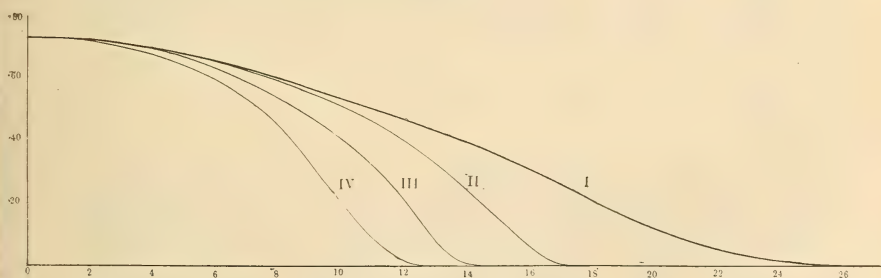
of this curve is of the form $V = 2 \frac{x^2}{\Delta^2}$, where x is difference of path in mm., V is visibility as a proper fraction, and Δ is the difference of path at which V falls to half its initial value.

Now the half-width of either of the two sodium lines giving such a curve is given by $\delta = \frac{22\lambda^2 \cdot 10^7}{\Delta}$, where λ , Δ are in mm. and δ in Ång. units.

It is thus seen that the broadening of the two sodium lines would be indicated by a more rapid falling off in this visibility curve.

The curves obtained by the writers are shown in fig. 2. (I)

2.



is the visibility curve obtained as above from the Bunsen flame, the magnet not being excited; while (IV) is the visibility curve when the magnetic field between the pole pieces was

in the neighborhood of 3000 C. G. S. units (estimated). The other two curves were taken with weaker fields. The relative strengths of field were in the same order as the shortening of the curves.

It is thus seen that the two sodium lines are broadened by the most intense field about in the ratio of 1 to 1.7, and less with weaker fields.

The effect is very decided when a difference of path of 10 to 18^{mm} is reached. The fringes are quite distinct with no magnetic field but are almost entirely obliterated when the current is turned on.

No special adjustment of the apparatus is necessary beyond that ordinarily required to obtain clear fringes.

The visibilities given are uncorrected eye estimates, but the results are so decided that it seems worth while to record this confirmation of Zeeman's discovery.

The writers intend to carry out immediately a more careful set of measurements along this line and hope soon to be able to communicate a more accurate set of results.

Physical Laboratory,
University of Kansas, April 15th, 1897.

May 10th, 1897.

Since the above note was written we have determined the amount of broadening in Ångström units produced by various magnetic fields of measured intensities. Using fields ranging from 0 to 7800 C. G. S. units, we have found that the percentage broadening is directly proportional to the field strength; the absolute amount for sodium in a unit field is 11.46×10^{-6} Ångström units. By percentage broadening is meant the increase in width divided by the original width of the line.

These results are in accord with the electromagnetic theory of Lorentz as given by Zeeman (Phil. Mag., March, 1897).

ART. LI.—*The relative Motion of the Earth and the Ether;*
by ALBERT A. MICHELSON.

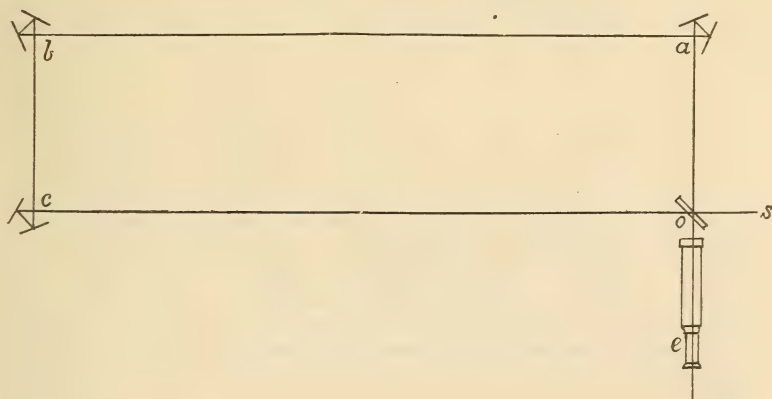
To account for the phenomenon of aberration Fresnel supposes the luminiferous ether at rest, the earth moving through this medium without communicating any perceptible part of its motion. On this theory it has been shown* that it should be possible to detect a difference of the velocity of light in two directions at right angles. As no such difference was observed, it would seem to follow that Fresnel's hypothesis is incorrect.

Another theory is that of Stokes, in which the aberration is accounted for if the relative velocity of the earth and the ether have a potential. This requirement, however, is inconsistent with the results of the experiment just cited, which indicates that at the earth's surface the relative motion is zero.

In the hope of detecting a relative motion corresponding to a difference of level, the following experiment was undertaken.

I take this opportunity of gratefully acknowledging the faithful and efficient services rendered in the execution of this work by Professor S. W. Stratton and Mr. C. R. Mann.

1.

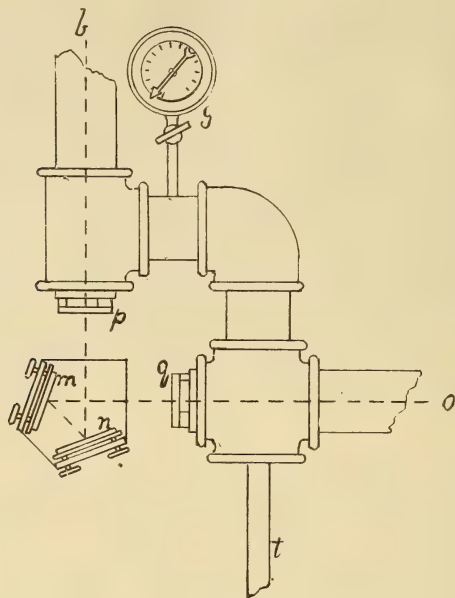


Light from the source *s*, a calcium light or an electric arc lamp, separated into two pencils at a plane-parallel glass plate, *o*, lightly silvered. The two pencils were reflected by double mirrors along the paths *oabco*, and *ocbaeo*, respectively. The two paths being equal, interference fringes could be observed with the aid of the telescope at *e*. Fig. 2 shows details of the corner at *c*: *pq* are plane-parallel glass disks, cemented to the

* This Journal, November, 1887.

ends of the iron pipes; mn , plane glass plates silvered on front surface, and provided with adjustments in two planes; $omnb$, the path of the pencil of light. The apparatus was set up in the vertical east and west plane, the light traversing the entire circuit of the Ryerson Laboratory, a path about 200 feet long and 50 feet high.

2.



It was found that under ordinary conditions the temperature disturbances in this length of air made it impossible to measure the position of the fringes; and the difficulty was only slightly remedied by enclosing the whole path of the light in a wooden box. By making this enclosure an iron pipe and exhausting the air to within a hundredth of an atmosphere, it was found possible to measure the position of the central bright fringe to within something like a twentieth of the fringe-width.

A difficulty is encountered in the selection of a fiducial mark. The double image of the source does not remain on the cross hairs of the observing telescope for any great length of time, notwithstanding the precaution of the double reflections at the corners, but by using this double image itself as the fiducial mark, any possible errors due to daily temperature changes, etc., are eliminated. This double image and the interference fringes are not in focus at the same time, but by sacrificing a very

little in the definition of each, the measurements may be made with very considerable precision.*

The observations were taken in the morning, at noon, evening and night; no special care being taken as to the exact hour. The results are summed up in the table containing the observations taken and reduced by Mr. Mann, as follows:—

The micrometer was set on one spot, then on the central fringe, then on the other spot, giving three readings of the micrometer. The first reading was subtracted from the third, giving the distance between the spots in divisions of the micrometer head. The second reading was subtracted from the third, giving the distance of the central fringe from the lower in divisions of the micrometer head. This last remainder was divided by the first, giving the distance n of the central fringe from the lower spot in fractions of the distance between the spots regarded as unity.

Each reading was reduced this way and the mean of ten taken as the result for any given time. The weights p were calculated as usual from the formula: $p = c/e^2$.

| Date. | 6 A. M. | | | 12 Noon. | | | 6 P. M. | | | 11 P. M. | | |
|----------|---------|-------------|--------|----------|-------------|--------|---------|-------------|--------|----------|-------------|--------|
| | n | p | pn | n | p | pn | n | p | pn | n | p | pn |
| March 11 | ·500 | 67 | 33·50 | ·515 | 40 | 20·60 | ·503 | 12 | 6·03 | ·480 | 20 | 9·60 |
| | ·513 | 38 | 19·49 | | | | ·506 | 10 | 5·06 | ·490 | 32 | 15·68 |
| March 13 | ·495 | 11 | 5·44 | ·530 | 33 | 17·49 | | | | | | |
| March 16 | ·507 | 55 | 27·88 | ·499 | 50 | 24·95 | ·492 | 13 | 6·40 | ·479 | 60 | 28·74 |
| | ·509 | 120 | 61·08 | ·491 | 45 | 22·09 | ·488 | 40 | 19·52 | ·487 | 22 | 10·71 |
| March 17 | ·490 | 40 | 19·60 | ·504 | 80 | 40·32 | ·500 | 35 | 17·50 | ·488 | 105 | 51·24 |
| | ·488 | 50 | 24·40 | ·502 | 60 | 30·12 | ·498 | 30 | 14·94 | ·496 | 100 | 49·60 |
| March 18 | ·501 | 80 | 40·08 | ·492 | 80 | 39·36 | ·493 | 40 | 19·72 | ·498 | 25 | 12·45 |
| | | | | ·507 | 50 | 25·35 | ·488 | 25 | 12·20 | ·498 | 35 | 17·43 |
| Sums. | | 461 | 231·47 | | 438 | 220·28 | | 205 | 101·37 | | 399 | 195·45 |
| Means. | | ·502 ± ·002 | | | ·503 ± ·003 | | | ·494 ± ·002 | | | ·490 ± ·002 | |

$$12 \text{ Noon} - 11 \text{ P. M.} = \cdot 013$$

$$1 \text{ fringe} = \cdot 250$$

$$\therefore \text{maximum displacement } \frac{13}{250} = \frac{1}{20} \text{ fringe.}$$

The conclusion from these results is that if there is any displacement of the fringes it is less than one-twentieth of a fringe.

If we consider the times occupied by the two pencils in com-

*On account of the inequality of the angles of incidence and reflection there will be a slight difference between the real and apparent positions of the double image. This difference will be altogether too minute to produce any appreciable error. Again, this difference in direction produces a difference in the length of the two paths—which is however of the second order and can also be neglected.

pleting their paths at noon and at midnight (when the horizontal parts of the path are parallel with the earth's motion in its orbit), we find the difference is $4s\frac{v}{V^2}$ where s is the length of the horizontal part of the path, v , the *difference* of relative velocities above and below, and V the velocity of light. This corresponds to a *displacement* $\Delta = 4\frac{s}{\lambda}\frac{v}{V}$ fringes.

If the relative motion be assumed to follow an exponential law it may be represented by

$$v = v_0(1 - e^{-kh})$$

where v_0 is the velocity of the earth and h , the height above the surface.

Suppose $\frac{v_0 - v}{v}$ falls to $\frac{1}{e}$ of its surface value in one hundred kilometers. Then in fifteen meters, which is the difference of level of the two horizontal pipes

$$v_0 - v_1 = .00015 v_0.$$

Substituting this for v in the equation for Δ we have

$$\Delta = .0006 \frac{s}{\lambda} \frac{v_0}{V}.$$

Putting $\frac{s}{\lambda} = 12 \times 10^7$ and $\frac{v_0}{V} = 10^{-4}$ we find $\Delta = 7.2$ fringes.

As the actual displacement was certainly less than a twentieth of a fringe, it would follow that the earth's influence upon the ether extended to distances of the order of the earth's diameter.*

Such a conclusion seems so improbable that one is inclined to return to the hypothesis of Fresnel and to try to reconcile in some other way the negative results obtained in the experiment cited in the first paragraph.

The only attempt of this character is due to H. A. Lorentz.† It involves the hypothesis that the length of bodies is altered by their motion through the ether.

In any case we are driven to extraordinary conclusions, and the choice lies between these three:—

1. The earth passes through the ether (or rather allows the ether to pass through its entire mass) without appreciable influence.
2. The length of all bodies is altered (equally ?) by their motion through the ether.
3. The earth in its motion drags with it the ether even at distances of many thousand kilometers from its surface.

* Of course this will depend on the law assumed for the rate of diminution of relative velocity with distance from the earth's surface; and possibly an exponential law is far from the truth. It may be desirable to repeat the experiment with a much greater difference of level, and perhaps to bury the lower tube some distance underground.

† "Versuch einer Theorie der El. u. Op. Erscheinungen in bewegten Körpern," H. A. Lorentz.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Relation of Refraction to Density.*—It is well known that Kopp distinguished between real and apparent molecular volume by defining the former as the space actually occupied by the molecule and the latter as this quantity increased by the space in which the molecule moves. TRAUBE prefers to call the former the molecular nucleus-volume and the latter the molecular vibration-volume; the nucleus-volume being the sum of the atomic nucleus-volumes, and the vibration-volume being the sum of the atomic vibration-volumes, increased by the space in which the molecule itself vibrates. Hence for this molecular vibration-volume, which is the quotient obtained by dividing the molecular mass by the density, we have $V_m = \Sigma nC + Cov$; i. e., the sum of the products of the vibration-volumes of the separate atoms by their number, increased by the molecular co-volume, which is constant and has the value 25.9. In a previous paper the author had shown that the molecular co-volumes of liquids, and probably of solids also, are equal, so that the laws of Avogadro and Gay Lussac apply to these states of matter. While therefore the passage from the solid to the liquid state is not accompanied by any change in the molecular co-volume, this value decreases when the liquid becomes a gas, the decrease being greater the higher the temperature. Hence for every substance there must be a particular temperature at which the co-volumes of the liquid and the gas are the same. This obviously is the critical temperature. Traube has now shown that if, according to the Clausius-Mosotti dielectric theory, v be the space actually filled with matter, and k the dielectric constant, the molecules being supposed spherical, $v = (k - 1)/(k + 2)$. But the dielectric constant, on the electromagnetic theory of light, is equal to the square of the index of refraction μ for waves of very great length. Hence as Exner has proved $v = (\mu^2 - 1)/(\mu^2 + 2)$. Moreover as above stated, this value is comparable to the expression $\Sigma nC/V_m$; so that the quotient of $\Sigma nC/V_m$ divided by $(\mu^2 - 1)/(\mu^2 + 2)$ should be a constant quantity. From the tabulated results of a long series of calculated values of this ratio it appears that the atomic vibration-volume calculated from the molecular mass and the density are equal to the atomic nucleus-volumes, obtained from atomic refraction, multiplied by a constant which varies only with the wave length of light and this within narrow limits. For D, this constant is 3.44; for Cauchy's constant A, it is 3.53.—*Ber. Berl. Chem. Ges.*, xxix, 2732-2742, December, 1896.

G. F. B.

2. *On the Properties of Free Hydrazine.*—According to LOBBY DE BRUYN, free hydrazine is best prepared by the action of barium oxide on hydrazine hydrate. The barium oxide is contained in a flask provided with a neck about 50^{cm} long bent at right angles

at its upper end so that it can be attached to the condenser directly. The hydrate is added in small quantities at a time, the mixture being kept cool during the action. The flask is heated for several hours in a glycerin bath at 110° – 120° and the contents are then distilled under a pressure of 150–100^{mm}, the apparatus being filled with dry hydrogen to prevent oxidation. The base, which collects in the cooled receiver, still contains 3 or 4 per cent of water, from which it is freed by re-distillation with barium oxide. The free hydrazine fuses at 1.4° ; though the liquid can be cooled several degrees lower before it freezes. Its boiling point, taken in dry hydrogen, is 56° at 71^{mm}, 113.5° at 761.5^{mm} and 134.6° at 1490^{mm} pressure. Its specific gravity at 15° is 1.014; about the same as that of the hydrate. In solubility hydrazine resembles both water and hydroxylamine. It is miscible in all proportions with methyl, ethyl, propyl, isobutyl and amyl alcohols. It combines with sodium chloride apparently, a considerable amount of heat being produced when these substances are mixed. They solidify to a crystalline mass on cooling. The base may be heated to 300° – 350° without perceptibly decomposing; a portion remaining unchanged even after being heated for an hour to the boiling point of sulphur. The critical temperature of hydrazine is 380° . Its stability at high temperatures depends on the pressure, the decomposition at first being $(N_2H_4)_2 = N_2 + H_2 + (NH_3)_2$ but subsequently changing to $(N_2H_4)_3 = N_2 + (NH_3)_4$. Hydrazine is a strong reducing agent, readily bursts into flame in chlorine and reacts violently with bromine and iodine. It is slowly oxidized in dry air and in oxygen; the temperature in the latter case rising to 100° . Sodium acts on this base when suspended in light petroleum yielding hydrogen, ammonia, and a brown, solid substance.—*Rec. Trav. Chim.*, xv, 174; *J. Chem. Soc.*, lxxii, 22, Jan., 1897. G. F. B.

3. *On Nitrogen Pentasulphide*.—Nitrogen pentasulphide N_2S_5 has been obtained by MUTHMANN and CLEVER by heating the nitrogen sulphide N_4S_4 with pure carbon disulphide for two hours at 100° under a pressure of five atmospheres. A deep red solution containing a yellowish-brown, amorphous precipitate is thus obtained, which is filtered and the filtrate distilled until most of the carbon disulphide is removed. The residue is then allowed to evaporate in a vacuum at the ordinary temperature. A red, oily product results, which consists of a mixture of the pentasulphide with sulphur. This is treated with dry ether to remove the pentasulphide, the last traces of sulphur being crystallized out by means of a freezing mixture. The ether is allowed to evaporate, the last traces being removed over calcium chloride. After filtering, the red oil, if pure, crystallizes from a well-cooled ethereal solution in tablets resembling iodine. The molecular mass determined cryoscopically, using benzene as the solvent, gave the formula N_2S_5 . The amorphous bye-product already mentioned gave the formula $C_8N_2S_3$. It is a fine yellow powder, is extremely hygroscopic and retains strongly traces of carbon

disulphide and the pentasulphide. Concentrated sulphuric acid dissolved it unchanged, and it resembles somewhat pseudocyanogen sulphide $C_3N_3S_3H$. Nitrogen pentasulphide may also be formed by the action of nitrogen sulphide on carbon tetrachloride, or by reducing thiotriethiazyl chloride N_3S_4Cl suspended in methyl alcohol by means of zinc dust. In general it results from the decomposition of nitrogen sulphide and its derivatives; as for example when this substance is exploded by friction, when its compounds with the halogens or with nitrous or nitric acid are boiled with water, and when it is heated cautiously with lead oxide. Nitrogen pentasulphide is a deep red liquid, with a sp. gr. of 1.901 at 18° . It does not wet glass, is partially decomposed when distilled even under diminished pressure, and when cooled in a freezing mixture solidifies to a crystalline mass resembling iodine, which fuses at 10° – 11° . It is insoluble in water, but dissolves in most organic solvents, its solution being stable when protected from light. Its absorption spectrum is characterized by a broad band extending from the D line into the blue. If a minute quantity of alcoholic potash or soda is added to its solution in alcohol, an intense violet-red coloration is produced transiently; this reaction serving to detect a very minute quantity.—*Zeitschr. anorg. Chem.*, xiii, 200–208, October, 1896. G. F. B.

4. *On the Direct Union of Carbon and Hydrogen.*—In Berthelot's experiments on the action of carbon on hydrogen at high temperatures, the only positive result obtained was the formation of acetylene when the electric arc was formed between carbon terminals in an atmosphere of hydrogen. BONE and JORDAN have re-investigated this subject, using for the purpose two different methods. In the first a current of hydrogen was passed over carefully purified sugar-charcoal contained in a porcelain tube heated in a Fletcher furnace to about 1200° . While the issuing gas contained no acetylene or other unsaturated hydrocarbon, there was present invariably about one per cent of a saturated hydrocarbon, probably methane. In the second method an electric arc was formed between terminals of purified carbon in an atmosphere of hydrogen. The products obtained were acetylene and methane. Experiments on the progress of the reaction showed a somewhat rapid production of both gases during the first half hour, while the amounts formed subsequently seemed gradually to approach a limit. Since this condition of equilibrium between hydrogen, methane and acetylene is of great interest, the authors produced the arc in an atmosphere either of methane or of acetylene, expecting that while at first the greater part of the methane or acetylene would be decomposed, there would finally be reached a condition of equilibrium similar to that obtained in the experiment with hydrogen. This was found to be the case. The authors sum up their results as follows: (1) At a temperature of 1200° or thereabouts, carbon unites directly with hydrogen to form methane, no acetylene or other unsaturated hydrocarbon being formed at this temperature. (2) When the electric arc is

produced between carbon terminals in an atmosphere of hydrogen, methane and acetylene are both formed; on continuing the passage of the arc a state of equilibrium between hydrogen, methane and acetylene is finally established. (3) The same state of equilibrium is produced when the electric arc is passed in an atmosphere of either methane or acetylene under similar conditions.—*J. Chem. Soc.*, lxxi, 41–61, January, 1897.

G. F. B.

5. *On the Preparation of Rubidium and its Dioxide.*—An improved process of obtaining metallic rubidium has been devised by ERDMANN and KÖTHNER, giving a yield of 85 per cent. Rubidium hydroxide, 20 grams, coarsely pulverized and mixed with ten grams of magnesium filings, is placed in the long arm of a seamless iron tube one meter long and 15^{mm} bore, having walls three millimeters thick, this tube being bent about 15^{cm} from one end at an angle of 125°. At the bend is placed a loose plug of clean steel turnings. The tube is placed in a combustion furnace and heated to redness while a current of hydrogen is passed through it. The short arm dips beneath the surface of some paraffin oil and as the temperature is gradually raised, the rapid escape of bubbles indicates that the reaction has begun. The heat is then shut off and after hydrogen ceases to be evolved from the hydroxide, the temperature is raised to a red heat and the metal distills over, 14 grams being obtained from the 20 grams of hydroxide used. The yield is very pure, the metal having a specific gravity of 1.5220 at 15° and a melting point of 38.5°. By the action of dry oxygen on the metal at the ordinary temperature, the dioxide is obtained. Since under these conditions, rubidium attacks glass, porcelain, platinum, silver and even rubidium chloride, the authors allow the metal to fall into an aluminum dish contained in a small glass flask filled with nitrogen; the whole being weighed both before and after the oxidation. When a current of oxygen is directed on the metal, it quickly melts and even inflames. With normal oxidation the metal preserves for a time the look of molten gold, then swells and becomes black and the absorption ceases. It is renewed however at 500°, the volume diminishes and a thick black liquid is produced, from which on cooling the dioxide crystallizes in dark brown plates. No evidence was obtained of any other oxide of rubidium, and this one may be highly heated without losing or taking up oxygen. Water acts on it violently, producing hydrogen peroxide and rubidium hydroxide, oxygen being evolved. Heated in an atmosphere of hydrogen, the dioxide yields the hydroxide, water and oxygen in accordance with the equation $(\text{RbO}_2)_2 + (\text{H}_2)_2 = (\text{RbOH})_2 + \text{H}_2\text{O}_2$.—*Ann. Chem. Pharm.*, ccxciv, 55–71, November, 1896.

G. F. B.

6. *On the Pyrogenic Reactions of Aliphatic Hydrocarbons.*—Experiments have been made by HABER on the action of high temperatures on aliphatic hydrocarbons, using for the purpose hexane, trimethylethylene, acetylene and benzene. By passing a current of the gas through a hot tube it was exposed to the high

temperature for a few seconds only and thus secondary reactions were avoided. He found that at 600° to 800° , neither carbon nor an appreciable amount of hydrogen was liberated, but that the actual change was a shifting of an atom of hydrogen, forming an olefine and either methane or ethane, the latter in the smaller quantity. Hexane yields amylene and methane, trimethylethylene gives methane also but ethylene in addition, a complete change of arrangement taking place. Thorpe and Young had noticed in 1873 that paraffin yields no hydrogen on distillation, but lower hydrocarbons, of nearly equal molecular mass. In the paraffins the union of carbon with carbon is thus more easily dissolved than the union of carbon with hydrogen. But with the aromatic hydrocarbons the opposite seems to be the fact, benzene for instance giving diphenyl and hydrogen; although its decomposition is more difficult than that of hexane. At 900° to 1000° however the pyrogenic reaction is quite different, coke, tar and hydrogen being formed, methane being the only resulting paraffin and ethylene the only olefine. Hence ethylene does not unite with hydrogen at this temperature. At 800° acetylene gives but little ethylene with much hydrogen. Methane is quite stable.—*Ber. Berl. Chem. Ges.*, xxix, 2691–2700, December, 1896. G. F. B.

7. *On the Explosive Properties of Acetylene*.—It has been shown by BERTHELOT and VIELLE that when acetylene under ordinary pressure is exposed to the action of the electric spark, of a red hot wire, or of an explosion of fulminate, the gas is decomposed only in the immediate vicinity; while when the gas is under pressure the result is quite different, the gas showing the ordinary character of explosive mixtures when the pressure exceeds two atmospheres. In this case the explosion rapidly spreads through the entire mass of the gas, which decomposes into hydrogen and finely divided bulky carbon. If the initial pressure be 21 kilos. per square centimeter, the pressure developed is ten times this value, the change being complete in 0.018 of a second. Liquid acetylene decomposes in the same way. Using 18 grams in a bomb of 48.96 cc capacity, the final pressure was 5564 kilos. per sq. centimeter, almost the equal of gun cotton. Simple shock seems incapable of causing acetylene to explode either in the gaseous or liquid state. If water be made to act on excess of calcium carbide in a closed vessel, the elevation of temperature may be sufficient to start the decomposition of the whole of the compressed gas.—*C. R.*, cxxiii, 523–530, October, 1896. G. F. B.

8. *On the form of the atoms*; by C. FOURLINNIE. Pamphlet, 8vo. Reims, 1896.—In this little work M. Fourlinnie has sought to solve the following problem: "Can we explain the properties of simple bodies by supposing that their atoms are composed of a single and homogeneous substance, but having geometrical forms which differ from one simple body to another?"

Limiting this investigation to the metalloids, the author arrives at the conclusion that the metalloids belonging to a single class according to Dumas possess atoms of the same form, but of dif-

ferent dimensions, while metalloids belonging to two different families have different atoms. Carrying this analogy further, M. Fourlinnie shows that these atomic forms ought to be regular polyhedrons; a conclusion perfectly in accord with the fact that only five regular polyhedrons exist, corresponding to the five families of Dumas.

For accomplishing this determination he is led to compare the volumes of different regular polyhedrons, and thus he finds that the volumes of the cube, the octahedron the dodecahedron and the icosahedron when circumscribed upon the same sphere are to each other as the numbers 19, 16, 14 and 12, which are respectively the atomic weights of fluorine, oxygen, nitrogen and carbon.

M. Fourlinnie is then naturally led to conclude that the simple bodies of the family of fluorine have cubic atoms; those of the family of oxygen octahedral atoms; those of the nitrogen family, dodecahedral; finally, those of the carbon family have atoms of the form of regular icosahedrons. By exclusion, the regular tetrahedron belongs to hydrogen. It results, further, that the simple bodies at the head of the columns, Fl , O , N , C , have atoms of the same apothem, a circumstance which arouses the hope that it will be possible, according to the prediction of M. Schutzenberger, to establish the decimals of the atomic weights by mathematical calculation.

After some interesting considerations upon the repulsive and attractive action of the atoms, the author examines the consequences of his theory from the point of view of the combination of atoms among themselves and of atomicity. When the atoms combine they assume a state of stable equilibrium when the axes, determined by the faces (apothems), or the summits are coincident to each other.

By aid of these considerations the double atomicity of oxygen easily explains itself. It is the same with the triple atomicity of nitrogen, and further, the coexistence of the atomicities 3 and 5 in this element receives a striking interpretation; in the first case the equilibrium is determined by the apothems, in the latter by the summits. For carbon the tetratomicity is more difficult; it necessitates an equilibrium partly according to the apothems and partly according to the summits.

The ingenious theories of M. Fourlinnie are certainly not beyond all criticism, but they recommend themselves, from their originality and their novelty, to the good will of the scientific world. They should be considered as the embryo of a novel theory which will perhaps throw a new light on the obscure question of the relations of the atomic weights to each other. It is probably the first time that there has been given a relation of a mathematical order between the numerical values of the atomic weights of the simple bodies at the head of the columns, fluorine, oxygen, nitrogen and carbon.—*From the French of G. Darzens, Bull. Soc. Chim.*, III, xv, 975.

H. L. W.

9. *Use of rapid electrical oscillations for determining dielectric constants.*—W. NERNST describes a modification of his well-known bridge for determining dielectric constants. It is a species of double transformer. A spark gap is placed in the primary of one transformer. The bridge combination is connected to the terminals of the secondary of this transformer. In place of a telephone there is substituted the primary of the second transformer and a spark gap is placed in the secondary of the latter transformer. The extinction of the spark in this secondary denotes a balance. The apparatus is suitable for the measure of the dielectric constants of conducting fluids. Electrolytic resistances can also be determined to the fraction of one per cent; disturbances from polarization do not enter.—*Wied. Ann.*, No. 4, 1897, pp. 600–624. J. T.

10. *Ultra-red rays.*—H. RUBENS and A. TROWBRIDGE reach the conclusion that it is possible by means of a double spectral separation by the help of two acute angled prisms of rock salt to detect the energy of the spectrum as far as 18μ , and that with the aid of sylvine prisms it is possible to extend this limit to 23μ .—*Wied. Ann.*, No. 4, 1897, pp. 724–739. J. T.

11. *Production of X-rays of different penetrative values.*—Mr. A. A. C. SWINTON states that the penetrative value of the X-rays increases with the degree of vacuum in which they are produced. At a certain vacuum the bones of the hand, for instance, are clearly seen; with a higher vacuum the flesh becomes very transparent, while the bones are still opaque. At a still higher vacuum the bones become nearly as transparent as the flesh; and finally, at the highest vacuum the whole hand shows only a faint shadow on the fluorescent screen. Similar effects can be produced with a constant vacuum by varying the power of the Ruhmkorf coil or by altering the distance between the cathode and the anti-cathodes. On the assumption that cathode rays consist of regularly charged molecules which are repelled from the similarly electrified cathode, with an initial velocity that depends upon the degree of electrical excitation of the cathode, the conditions which produce X-rays of high penetrative value are those which would conduce to a high average velocity of the molecules at the moment they strike the anti-cathode and to a high average difference of potential between the travelling molecules and the anti-cathode at the moment of impact. The conditions for X-rays of low penetrative power are those which conduce to a lower average velocity of the molecules and to a less difference of potential between the latter and the anti-cathode. The quantity of X-rays is independent of the material of which the anti-cathode surface is made: anti-cathodes of aluminum, iron, copper, silver and platinum give X-rays of the same penetrative power.—*Nature*, April 29, 1897, p. 621. J. T.

12. *Physiological effects of the X-rays.*—M. SOREL discusses the pathological and physiological effects of the X-rays and believes that it is inadvisable to use the rays on portions of the human

body in the regions of important organs, like the heart or lungs. He finds a dead cold body more opaque to the rays than a dead body which is still warm. (Academy of Arts and Sciences, Paris, April 12.) W. Crookes, working on the same subject, believes that the physiological effects of the X-rays vary greatly with the idiosyncrasy of the experimenter; for he finds no injurious effects to himself even after prolonged exposure.—*Academy of Sciences*, Paris, April 20. J. T.

13. *Influence of magnetism on the nature of light emitted by a substance*.—Dr. P. ZEEMAN has observed that the spectral lines of sodium are broadened in a strong magnetic field.* Professor Lorentz's theory of the motions of ions in a magnetic field demands that the edges of the lines of the spectrum should be circularly polarized; the amount of widening can also be used to determine the ratio between charge and mass when a particle is giving out vibrations of light. Dr. Zeeman states that he has fully confirmed this theoretical deduction of Professor Lorentz by experiment.—*Phil. Mag.*, March, 1897, pp. 226-239. J. T.

14. *First Principles of Natural Philosophy*; by A. E. DOLEBEAR, pp. 318, 12mo, Boston and London, 1897. (Ginn & Co.)—This little book contains a brief statement of physical principles and phenomena put in simple form for elementary students. A questionable feature of the work is the change of the usually accepted nomenclature of science in some respects, as where the word *pressure* is used for *force* in discussing energy and work.

I. GEOLOGY AND MINERALOGY.

1. *Congrès géologique international*.—A third circular, issued by the committee of organization of the geological congress to be held in Russia this summer, contains the following important information. Regarding the scientific program for the session of the congress, the committee announce as their opinion that, before taking up the other questions left undecided by previous sessions, the congress should decide which of these two classifications they desire to preserve in science, viz: the *artificial* classification, based entirely upon historical data, or the *natural* classification, which is based as much upon general physico-geographical changes, common to all the terrestrial globe, as upon faunistic data, and not upon the accidental limits of the different divisions, called after the name of the country where they have been first determined. The data upon which the science actually rests are sufficiently numerous for sketching the principal outlines of the great physico-geographic changes, such as transgression of the seas, the relations between these and general oscillations of the continents, the phenomena of dislocation, etc. The comparison of these data with the faunistic data will doubtless make it possible to introduce a new grouping of the geologic systems and to stop the continual fruitless polemics which arise from the efforts one is obliged to make to put all the new facts, which the

* See further p. 472 of this number.

diverse regions offer, into the framework of the actual systems. After the examination of these first points, it is greatly to be desired that a decision be reached on a second question of principle, viz: that of the rules to be followed in the introduction of new terms in *stratigraphic nomenclature*. Every one knows how new denominations for indicating the different geological divisions have been appearing in literature. Often the authors of the new terms introduce them without any argument, either petrographic or faunistic, which may serve to distinguish, in a clear manner, the sediments to which the denominations are applied from the neighboring deposits; it often happens that the authors themselves have a very vague notion of the criteria by which they apply the name. Such new terms evidently being only useless incumbrances to the science, it is greatly to be desired that the congress, which has already established rules to be followed in paleontological nomenclature, pronounce also on the question of stratigraphic nomenclature and that it establish the data upon which the application of new denominations to particular deposits be authorized.

Another question, considered to be of no less importance by the committee, is the determination of the principles to be applied in the application of *petrographic nomenclature*. The flood of new terms in this science has attained such dimensions, that soon no one's memory will be able to retain all and the reader of each memoir will be obliged to employ a special glossary. The works undertaken in this direction should be accomplished simultaneously with the deliberations regarding the principles of petrographic classification, the elaboration of which was entrusted by the congress of Zurich to a special commission under the presidency of M. A. Michel-Levy.

Regarding excursions, the committee announces an additional excursion to the *Tséïsky glacier*. The number of participants is restricted to 25 persons.

Excursion C to Finland will cost 130 francs, instead of 50 frcs. as previously announced.

In response to several letters recently received, the committee of organization finds it necessary to state that the passes (*billets gratuits*) over the Russian railroads will be good from July 22d to October 17th. The tickets will give to the geologists the right to pass from the frontier to the points of departure of the excursions (St. Petersburg, Moscow, etc.) and to take part in all the parts of the itineraries of the proposed excursions. They will also be valid for the return of the excursionists to the frontier from whatever point they may choose to leave the excursions.

The committee receives daily requests for admission to the excursions on the part of students of special high schools and of foreign universities. While appreciating the benefit the excursions would be to these young men, the committee finds itself, to its deep regret, unable to admit students, either foreign or Russian, to the excursions, on account of the great number of geolo-

gists who have already inscribed themselves as members of the congress, and because the number of persons who can participate in the excursions is necessarily restricted.

H. S. W.

2. *Geological Survey of Canada*.—Three new Reports have appeared: viz.—

No. 584. Part L. Annual Report, vol. viii.—Report on explorations in the Labrador Peninsula along the East Main, Koksoak, Hamilton, Mamcaugan and portions of other rivers in 1892–93–94–95, by A. P. Low. pp. 1–387, four plates and four map sheets (585, 586, 587, 588).

No. 601. Part D. Ann. Rept., vol. viii.—Report on the country between Athabasca Lake and Churchill River, etc., by J. BURR TYRRELL assisted by D. B. DOWLING; pp. 1–120, three plates and map sheet (597).

No. 615. Paleozoic Fossils, vol. iii., Part iii.—The fossils of the Galena-Trenton and Black River formations of Lake Winnipeg and its vicinity, by J. F. WHITEAVES. pp. 129–242, plates xvi–xxii.

Mr. Low's Report on the Labrador peninsula is a particularly complete report on this little known region. In the opening pages a summary account is given of previous discoveries and explorations. Notes on the climate and population are given in addition to the description of the physical and geological characters of the district traversed. Appended to the report are Lists of the Mammals,—of the Birds,—of the principal Food Fishes,—of the Insects of the interior,—notes on the microscopic structure of rocks,—a list of plants and meteorological observations in 1893–1894 and 1895.

Mr. Whiteaves' Report on the Lake Winnipeg Ordovician forms contains the following remarks upon the gigantic size of fossils of this region:

“One of the most striking features in the fossils of the Winnipeg and Red River limestones is the large size to which many of the specimens attain, though this is more particularly the case with the Cephalopoda. Thus, one of the *Receptaculitidæ* (*Receptaculites Oweni*), which is abundant in these limestones, is known to attain to a size of twelve or even twenty inches in diameter. Some specimens of a simple Cyathophylloid coral (*Streptelasma robustum*) from Lower Fort Garry are nearly seven inches in length, as measured along the convex curve, and nearly five inches in height. A brachiopod from the same locality (*Rafinesquina lata*) is rather more than three inches in length at the hinge line, and a specimen of *Strophomena incurvata* from East Selkirk is fully double the usual size of that species. One of the gastropods (*Maclurea Manitobensis*) of these limestones is sometimes as much as eight inches and a half in diameter, and another, (the *Hormotoma Winnipegensis* of this Report) is eight inches long. The “gigantic Orthoceratites” noticed by Sir John Richardson on the west side of Lake Winnipeg, have already been referred to, but these are from localities north of the Saskatchewan.

South of that river, at Dog Head, specimens of *Orthoceratites* " (probably of *Endoceras subannulatum*), four feet and a half or even six feet in length, and imperfect at both ends, were observed by Mr. Lambe in 1890. A siphoncle of *Endoceras crassisiphonatum*, which is also imperfect at both ends, is nearly three feet long. A specimen, which appears to be a cast of the anterior end of the body chamber of a specimen of a *Poterioceras* (probably *P. nobile*), recently collected by D. B. Dowling and L. M. Lambe at Berens Island, and showing the infolding of the lip, is seven inches across. Rough casts of the interior of spirally coiled discoidal or nearly discoidal shells, apparently allied to *Barrandeoceras*, from several localities on the west shore of Lake Winnipeg, are nearly or quite two feet across. Lastly, a free cheek of a trilobite, *Asaphus* (*Isotelus*) *gigas*, from Cat Head, indicates a specimen that must have been twenty inches in length when alive; and other similar examples could be given."

3. *A guide to the fossil invertebrates and plants in the department of geology and palaeontology in the British Museum* (*Natural History*); pp. 1-158, figs. 1-182, 1897.—This guide, though of local value, primarily, is an admirable presentation of the most conspicuous features of fossil invertebrates, and the diagrammatic figures are selected with a view to make clear the distinctive characters of the several types of organisms, so as to be useful to one examining any well-equipped museum.

4. *The sea mills of Cephalonia*; by F. W. CROSBY and W. O. CROSBY; "Technology Quarterly," vol. ix, no. 1, pp. 6-23. The authors give a geologist's account of the famous sea mills near Argostoli, based upon personal examination. They associate the disposal of the downward-flowing waters with the formation of extensive and deep-seated fissures by earthquake, the return exit of which is supposed to appear in the numerous thermal springs of the region.

5. *Geologischer Wegweiser durch das Dresdner Elbthalgebiet zwischen Meissen und Tetschen*; von Dr. R. Beck; pp. 1-162 and maps. (Gebrüder Borntraeger) Berlin, 1897.—This is a handy pocket guide for geologists or mineralogists who may be spending the summer in the neighborhood of Dresden.

6. *Lawsonite*.—The new species lawsonite, described in 1895 by Ransome from Tiburon, Marin Co., California, has recently been identified by Franchi and Stella in the metamorphic rocks of the Piedmont Alps. It was first observed in an altered diabase near Elva in the Val Maira and since then it has been found to occur not infrequently in veinlets in a sodic amphibolite from the valley of Chianale. Its origin is regarded as similar to that of the epidote and zoisite common in the greenstones of the Alps.—*Bull. Soc. Min.*, xx, 5.

7. *A preliminary report on the Corundum deposits of Georgia*.—The administrative report of the State Geologist of Georgia, Mr. W. S. Yeates, was issued not long since, and with this were distributed Bulletin No. 1, a Preliminary Report on the Marbles

of Georgia by S. W. McCallie (previously noticed in the Journal), and Bulletin No. 2, giving a Preliminary Report on the Corundum Deposits of Georgia, by Francis P. King. This latter report, after a general account of the characters of the species and associated minerals, discusses at some length the special corundum deposits of Georgia. It will be found by all interested of much value as bringing together many facts and observations on the general subject with, further, a considerable amount of new matter.

III. BOTANY.

1. *Practical Botany for Beginners*; by F. O. BOWER, F. R. S., Regius Professor of Botany in the University of Glasgow. Macmillan and Co., London, 1894.

Guide to the Study of Common Plants, an Introduction to Botany; by VOLNEY M. SPALDING, Professor of Botany in the University of Michigan. D. C. Heath and Co., Boston, 1895.

The Elements of Botany; by FRANCIS DARWIN, F. R. S., Reader in Botany in Cambridge University. University Press, Cambridge (England) 1895.

Elements of Botany; by J. Y. BERGEN, A. M., Instructor in Biology, English High School, Boston. Ginn and Co. Boston, 1896.

Laboratory Practice for Beginners in Botany; by WILLIAM A. SETCHELL, Ph.D., Professor of Botany in the University of California. The Macmillan Company, New York, 1897.

Lessons in Elementary Botany for Secondary Schools; by THOMAS H. MACBRIDE, State University of Iowa. Allyn and Bacon, Boston, 1896.

In the list given above, we have enumerated a few of the latest works for beginners in Botany, not forgetting that there are earlier books on the same subject, or some aspects of it, which are by no means yet out of date. In such longer list would appear the names of many authors whose efforts in behalf of sound botanical training have yielded good results; results which have, in fact, been so good that some persons might be tempted to ask a few questions regarding the necessity of these newer handbooks. But, of course the answer is perfectly simple; every instructor has, or should have, decided views as to the best method of presenting the subject, and especially as to the best plan for beginning work. It is therefore of advantage to have a multiplicity of elementary treatises, provided they are not misleading: by inspection of these the teacher of beginners can compare different methods and select for his own pupils the one which comes nearest to his own ideal. We do not mean to say that all possible methods are likely to find their way into print, but we do think that at least some of the best are sure to be published. Further, we think that the handbooks heading this notice will, if taken in conjunction with a few others which will naturally

occur to the reader, and which are probably already in his hands, cover the chief types of dogmatic teaching and of laboratory work in Botany. Confining our notice to the half dozen here mentioned, we may say that the order in which they are arranged, although substantially chronological, represents a scale of decreasing difficulty and diminishing scope. In their respective works, Professor Bower and Professor Spalding seek to lead the student over a very large field of morphological and histological study, leaving little to be done as preliminary to special botanical research. Professor Bower's book is a trifle more technical in its treatment: Professor Spalding devotes rather more attention to matters of relationship.

The works by Mr. Darwin and Mr. Bergen are essentially of one type. They deal with the elements of morphology, histology, and physiology, drawing the mind of the pupils very early in the direction of habits. Mr. Bergen's handbook has also a short account of the most common plants of the northern and middle States, as a sort of introduction to work with some manual or flora.

The works by Professor Setchell and Professor MacBride form a third category. These are distinctly more elementary than the foregoing, both in scope and treatment, the latter being the simpler of the two. Both give much attention to morphology, to habits, and to adaptations. They discard the use of the compound microscope, and make the studies depend, where this is necessary, on the simple lens. With these six excellent types before us, it is difficult to see where a new handbook could find a place. Certainly, with these and with the earlier handbooks, every teacher of botany in our secondary schools ought to be able to put himself and his classes in possession of an acceptable manual adapted to the particular case.

G. L. G.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Researches on the Evolution of Stellar Systems. Vol. I. On the Universality of the Law of Gravitation and on the Orbits and General Characteristics of Binary Stars*; by T. J. J. SEE. pp. 258, 4to. Lynn, Mass., 1896. — Mr. See's volume is attractive from its elegant and carefully finished form, while its fullness of detail in all matters relating to double stars makes it a most useful hand-book. Its value consists, however, not chiefly in its statistics, valuable as these are, but in the use which the author makes of statistics for theoretical research, and for the emphasis with which he presents the claims of the astronomy of binaries to a place of the first importance.

The processes of weighing and measuring which are well nigh brought to completion within the solar system have scarcely begun among the infinities of space and matter beyond its limits. Unless some means can be found to advance from these beginnings until columns become volumes, the prospect of carrying any

researches in cosmogony beyond the present stage of surmise and unverified speculation seems hopeless. The clearest line of progress for the immediate future appears to be among the binaries. The forty definite orbits, which represent the work of a century since Herschel, furnish the basis for considerable safe generalization, and their number is likely soon to be materially increased from the long list of close doubles discovered by Burnham and others, among which there should be many cases of rapid motion.

Mr. See develops very simply a method, based on the hodograph, whereby motion in the line of sight can be very effectively employed to determine the linear dimensions, mass and distance of a binary independent of parallax. The range of this method is limited only by the resolvability of the pair. Parallax reaches to about 20 light years, the latter method to 2000.

The best example of Mr. See's ability to make statistics fruitful is seen in his discussion of the eccentricity of binary orbits. That this is usually large, every astronomer knows. (The average for 40 orbits is 0.48) but no one has hitherto emphasized the fact that this corresponds to a physical cause necessarily of prime importance. A suggestion by the late Professor Kirkwood made in this Journal as early as 1864 is, so far as the present writer is aware, the only word previously spoken on the subject. Mr. See's explanation is, briefly, that the primitive orbit was of small eccentricity, as under the controlling influence of a centrifugal tendency in a tolerably homogeneous mass it might be expected to be, but that the enormous tidal friction which must arise in a binary system would produce perturbations so great as to push the eccentricity even to the limit of unstable equilibrium. Tides of such efficiency require that the component masses should be of the same order of magnitude. This is true without exception in all known orbits. The next volume will perhaps deal more particularly with the effects of tidal disturbances acting under these conditions.

W. B.

2. *Annals of the Astronomical Observatory of Harvard College*.—Recent publications are the following: Vol. xxxvi. Journal of the Zone Observations of Stars between $49^{\circ} 50'$ and $55^{\circ} 10'$ of North Declination in 1855.0 and observed with the Meridian Circle during the years 1875 to 1885, under the direction of Joseph Winlock and Edward C. Pickering, Successive Directors of the Observatory; by William A. Rogers, 1896.

Also vol. xxviii, Part I, Spectra of Bright Stars photographed with the 11-inch Draper Telescope as a part of the Henry Draper Memorial and discussed by Antonia C. Maury under the direction of Edward C. Pickering, Director of the Observatory.

3. *Geographische Abhandlungen*. Herausgegeben von Prof. Dr. ALBRECHT PENCK in Wien.—To the geographical memoirs edited by Prof. Penck in Vienna have been added the following: Volume v, No. 5, is devoted to a paper on the precipitation in Bohemia by Dr. Vasa Ruvarac, and one on the evaporation and flow from large surfaces of land, by Prof. Penck. Volume vi,

No. 1, discusses the features of the beautiful lakes of the Salzkammergut, and the Austrian Traun by Dr. Johann Müllner. This paper serves as an explanation to accompany the first part of the Atlas of the Austrian Lakes.

4. *Beiträge zur Geophysik: Zeitschrift für physikalische Erdkunde.* Herausgegeben von Prof. Dr. GEORG GERLAND. III Band, 1 Heft, Leipzig (Wilhelm Engelmann. 1896.) This first part of volume iii contains a series of valuable memoirs. From one of them, devoted to the *Aurora Australis*, we quote the accompanying figure showing the distribution of the southern

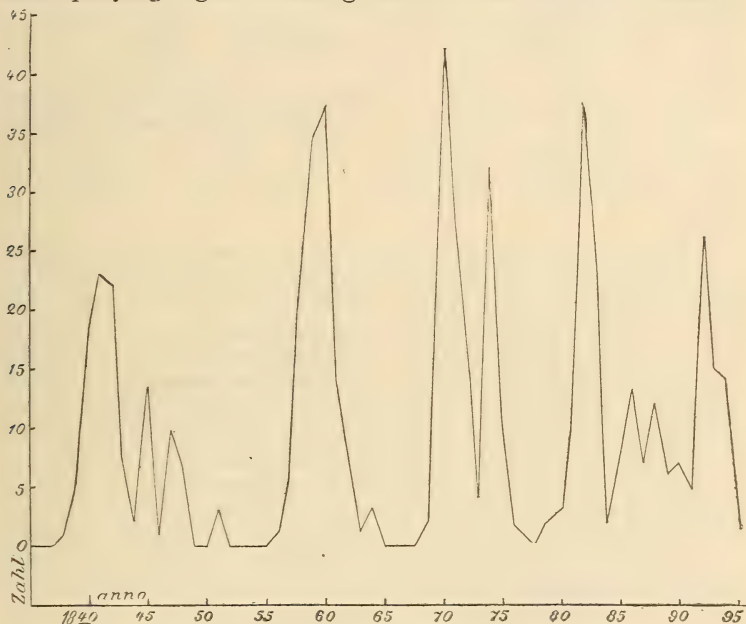


Fig. 1.

aurora during the years from 1835 to 1895. It is interesting as bringing out clearly the ten-to-eleven-year period which has been so well established for the northern aurora. This article gives an interesting discussion of the general subject of the *Aurora Australis* with the enumeration of many observations.

5. *Lavori eseguiti nell'Istituto di Fisica dell'Università di Pisa, diretto dal Prof. A. BATTELLI* (Anno Scolastico, 1895-6), vol. i, pp. 214. Pisa, 1896.—This volume contains researches carried out in the Physical Institute of the University of Pisa, being reprints from *Il Nuovo Cimento*, of which Professor Battelli is one of the editors. Of the sixteen papers which it contains, three are by Professor Battelli alone and five are in conjunction with Dr. Garbasso, all of the latter having reference to the Röntgen rays. They constitute very valuable contributions to this interesting subject. An experiment given by Garbasso to show the dif-

ferences in the dielectric constant is simple and ingenious. The two plates of an Epinus condenser, somewhat separated, are connected, the one with a charged Leyden jar, the other with a gold leaf electroscope. On placing various dielectrics between the plates, the divergence of the leaves increases in proportion as the dielectric constant is greater.

G. F. B.

6. *Ostwald's Klassiker der exakten Wissenschaften*.—The following additions have been made to this valuable series of scientific classics:

Nr. 80. *Theorie der Luftschwingungen in Röhren mit Offenen Enden* von H. Helmholtz. (1859.) 132 pp.

Nr. 81. *Experimental-Untersuchungen über Elektrizität* von Michael Faraday. 1 und 11 Reihe. (1832.) 96 pp.

Nr. 82, 83. *Systematische Entwicklung der Abhängigkeit geometrischer Gestalten von einander, mit Berücksichtigung der Arbeiten alter und neuer Geometer über Porismen, Projections-Methoden, Geometrie der Lage, Transversalen, Dualität, und Reciprocität, etc.*, von Jacob Steiner. I Theil., 126 pp., II Theil., 162 pp.

7. *La cause première d'après les données expérimentales*; by ÉMILE FERRIÈRE; pp. 462. (Paris: Felix Alcan, 1897.)—In two previous works the author has reached the conclusions that there is a unity to the laws of matter and energy throughout the universe; a substantial identity of matter and energy; a unity of life in plants and animals; the soul ("l'Ame") is the function of the brain. In the present work, he completes the series of his investigations, which he has undertaken in the spirit of Claude Bernard, and reaches the conclusion that there is one substance, the exterior manifestation of which is matter-energy. When this permanent source or substance is viewed from the point of view of truth, it takes the name of primary cause; when viewed from the point of view of the real, it is the world. In discussing these metaphysical points the author gives an elaborate synopsis of the creation of the animal and of the vegetable kingdom.

8. *Den Norske Nordhavs-Expedition 1876-1878*. Christiania, 1896.—Part XXIII of the seventh volume of this most valuable work, devoted to the results of the Norwegian North Atlantic Expedition, has recently been issued. It contains the following papers on the Tunicata: 1. Synascidiæ. 2. Ascidie Simplicies og Ascidie Compositæ. 3. Fortegnelse over Norges Ascidie Simplicies. 4. Om Knopskydningen hos Distaplia Magnilarva og Pyrosoma Elegans. 5. Kimbladstudier paa Grundlag af Ascidierne Udvikling. Christiania, 1896: Grondahl & Sons.

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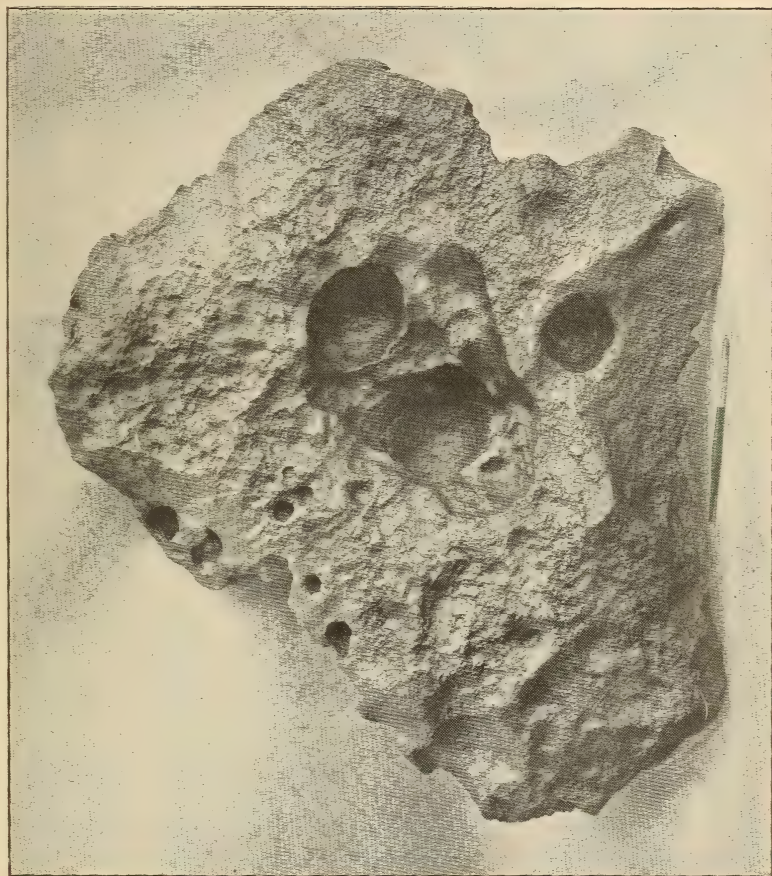
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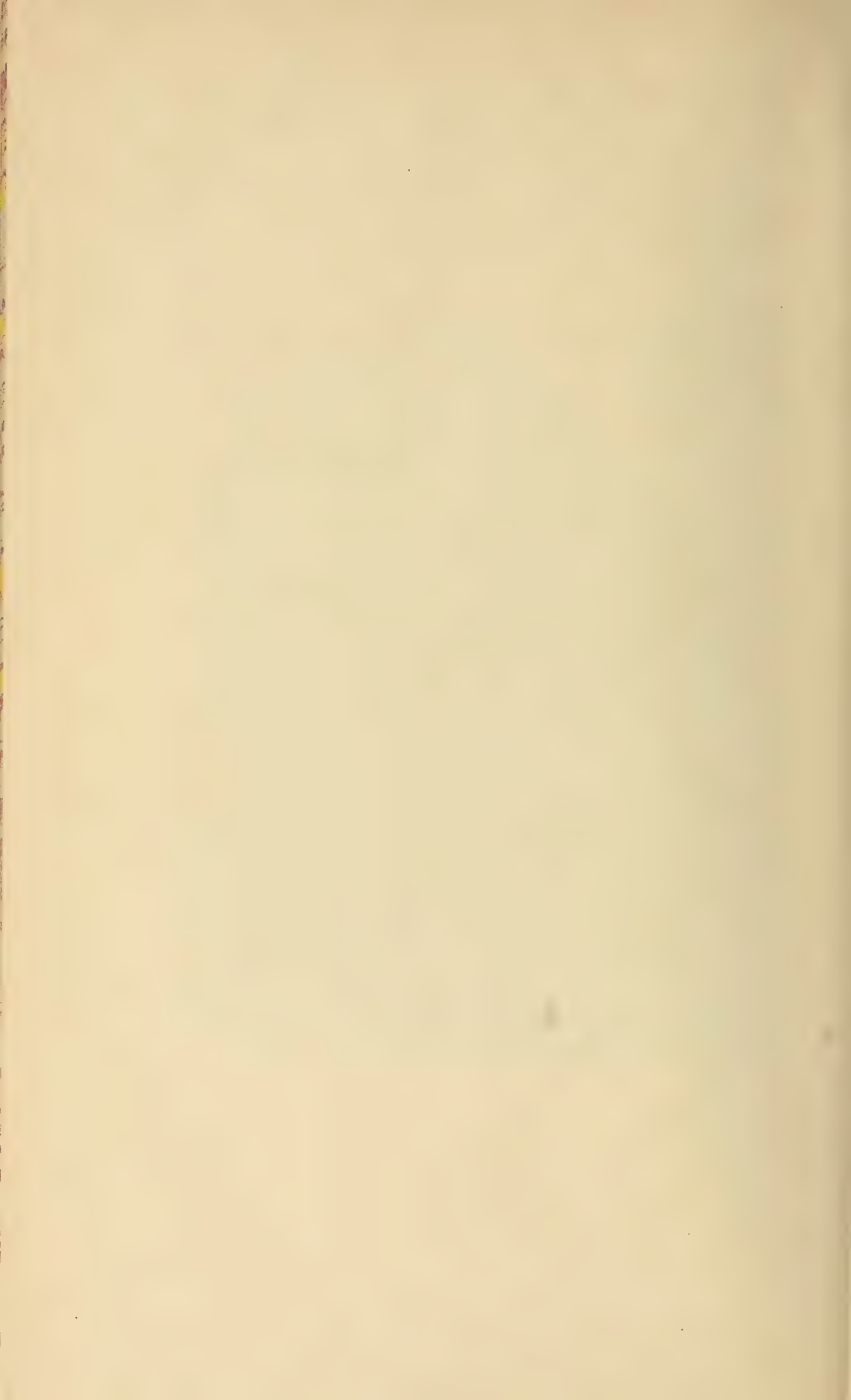
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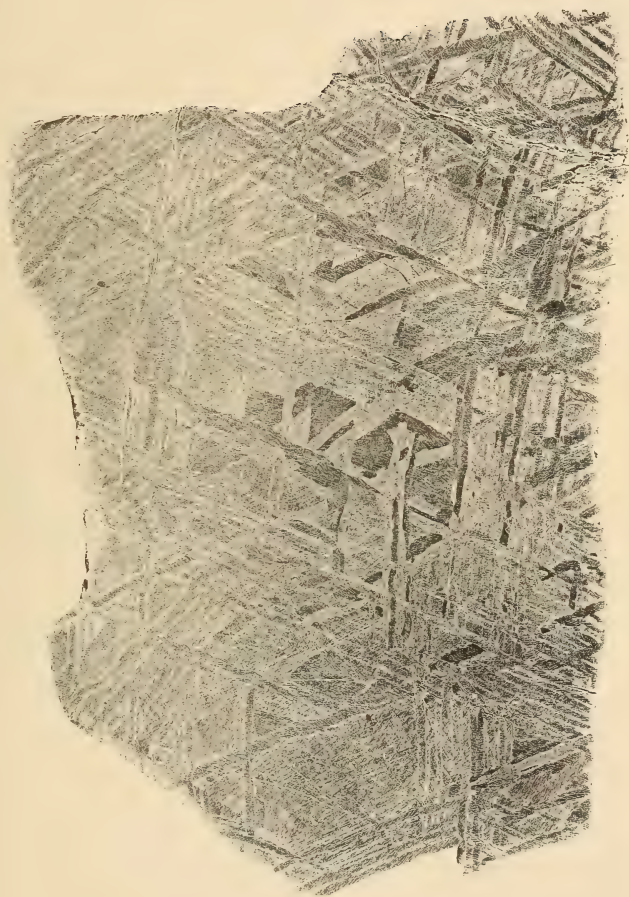
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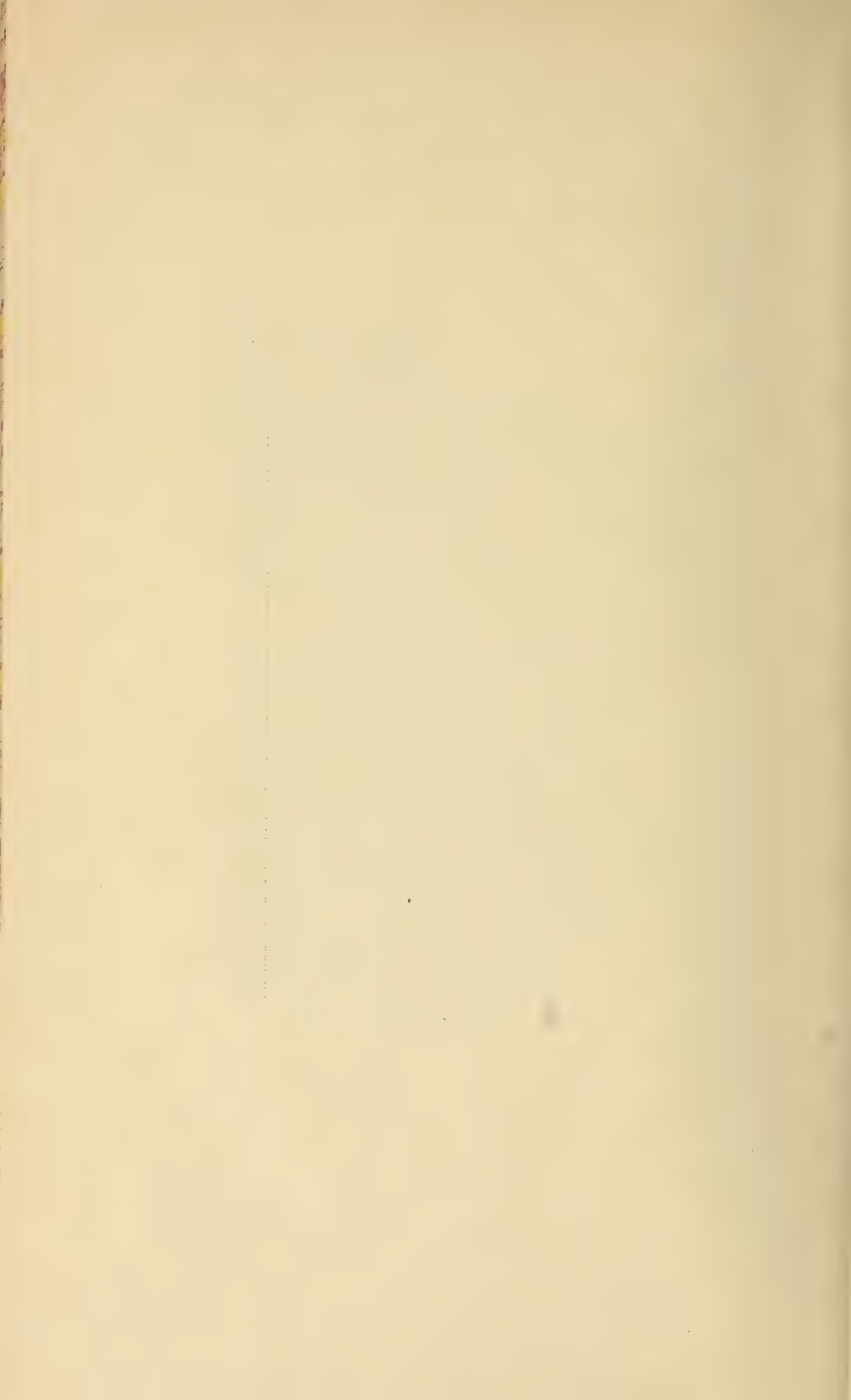


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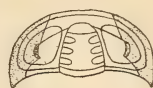
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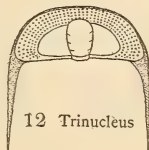
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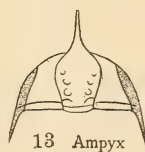
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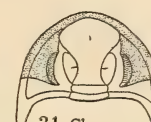
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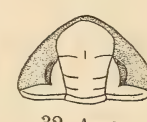
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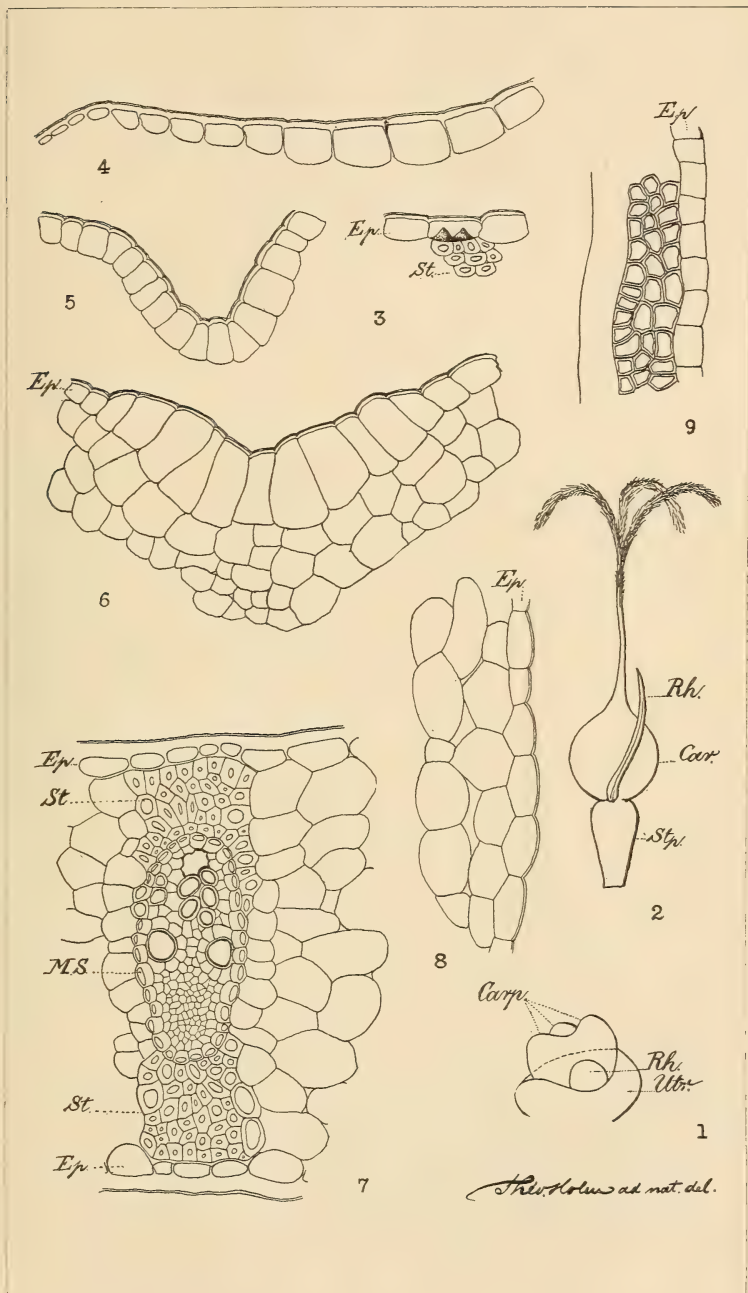


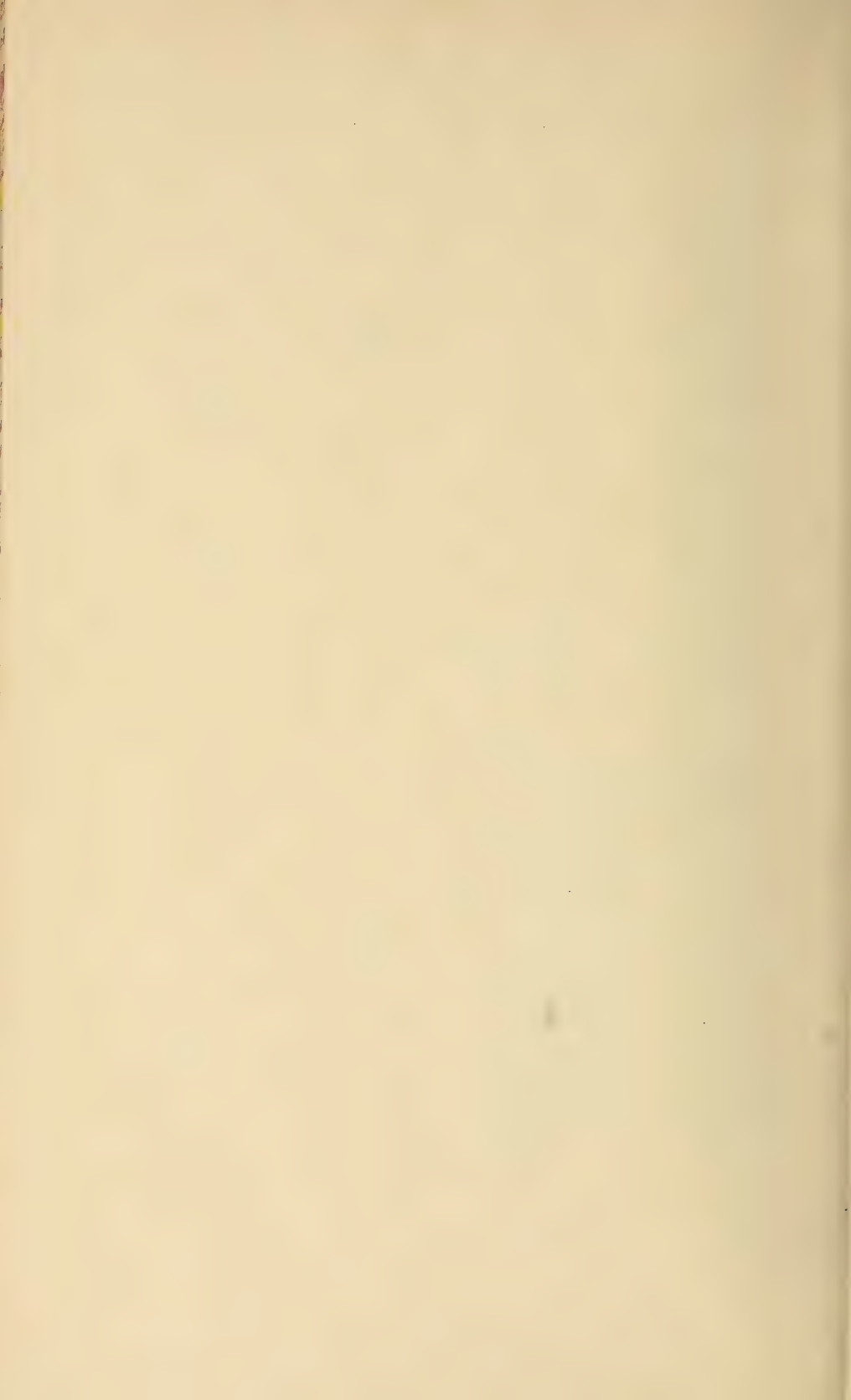
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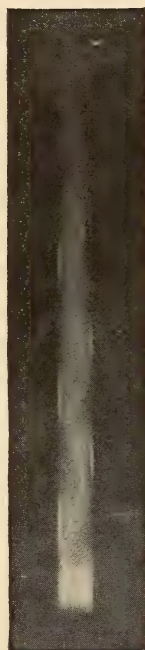


View across the western part of Crator lake. The Devil's Backbone and Liao Rock seen beyond Wizard island.

1.



2.



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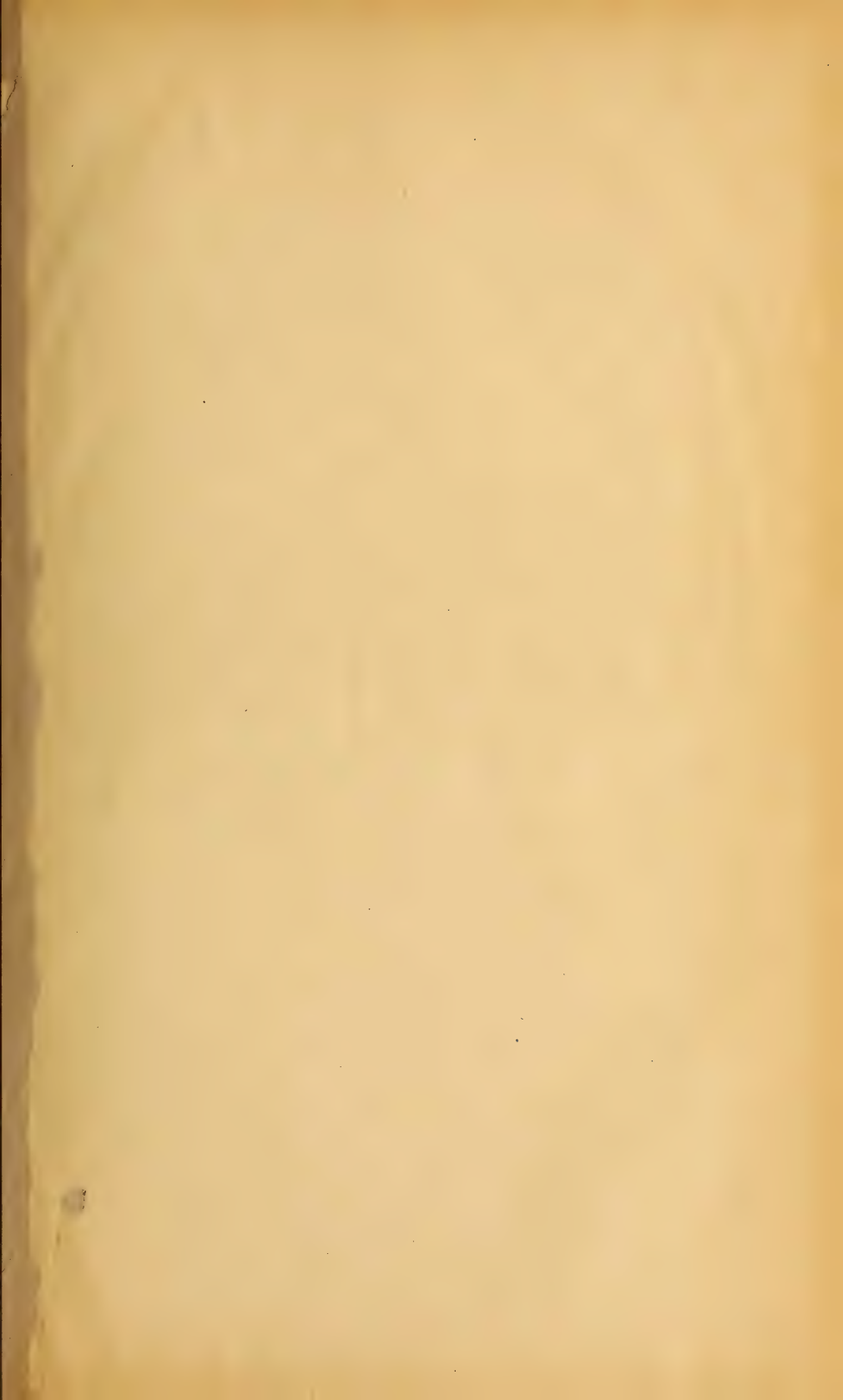
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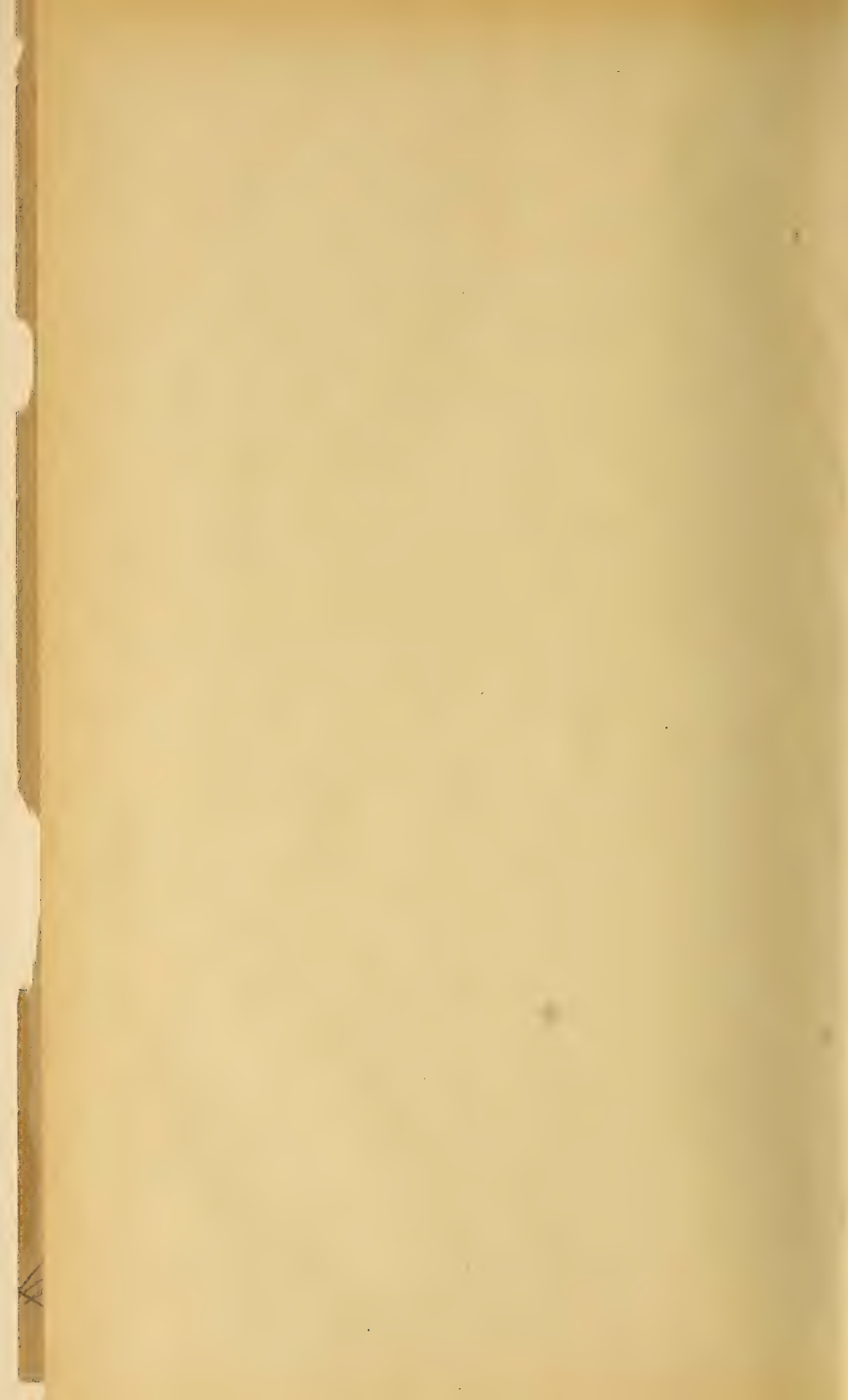
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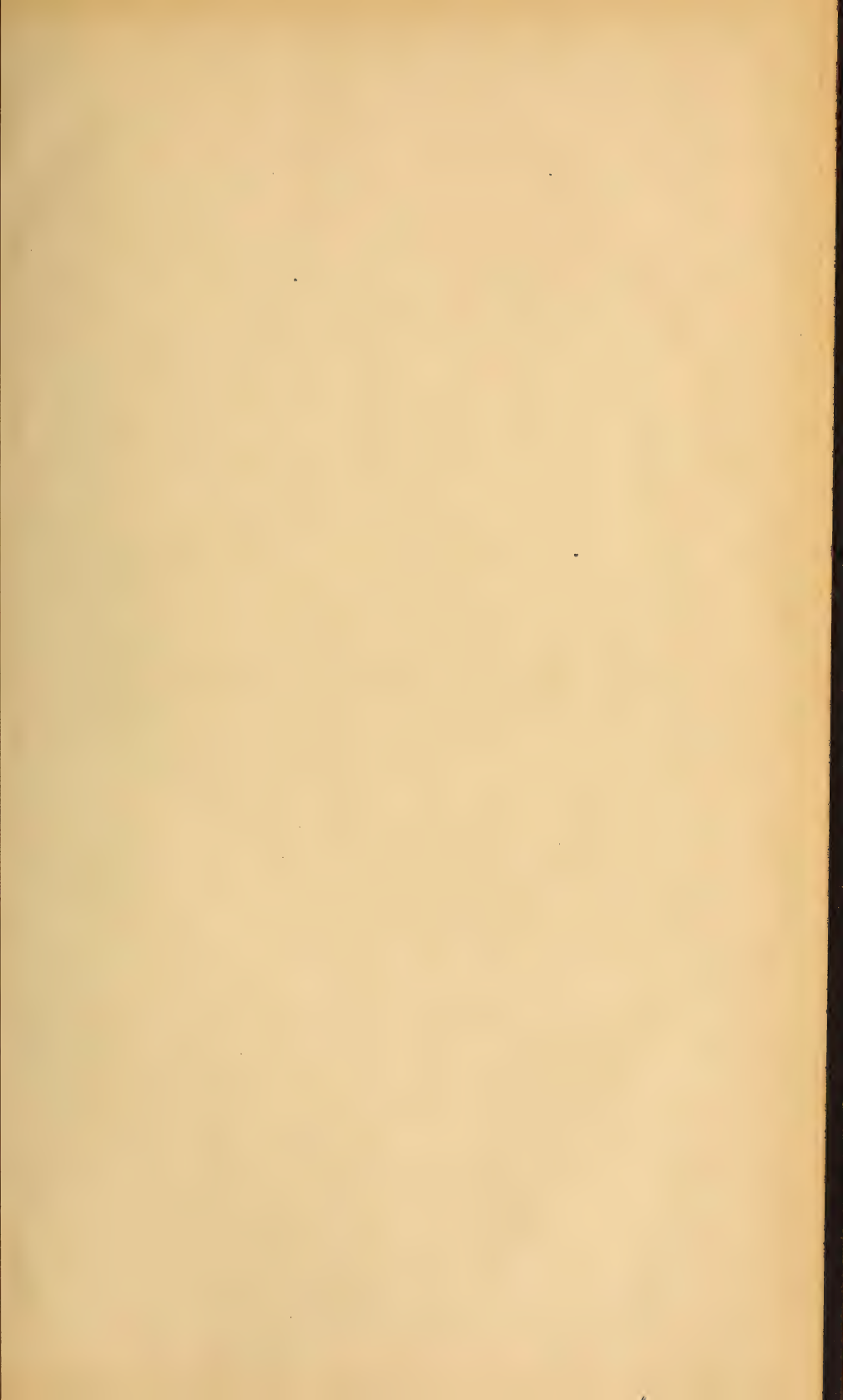
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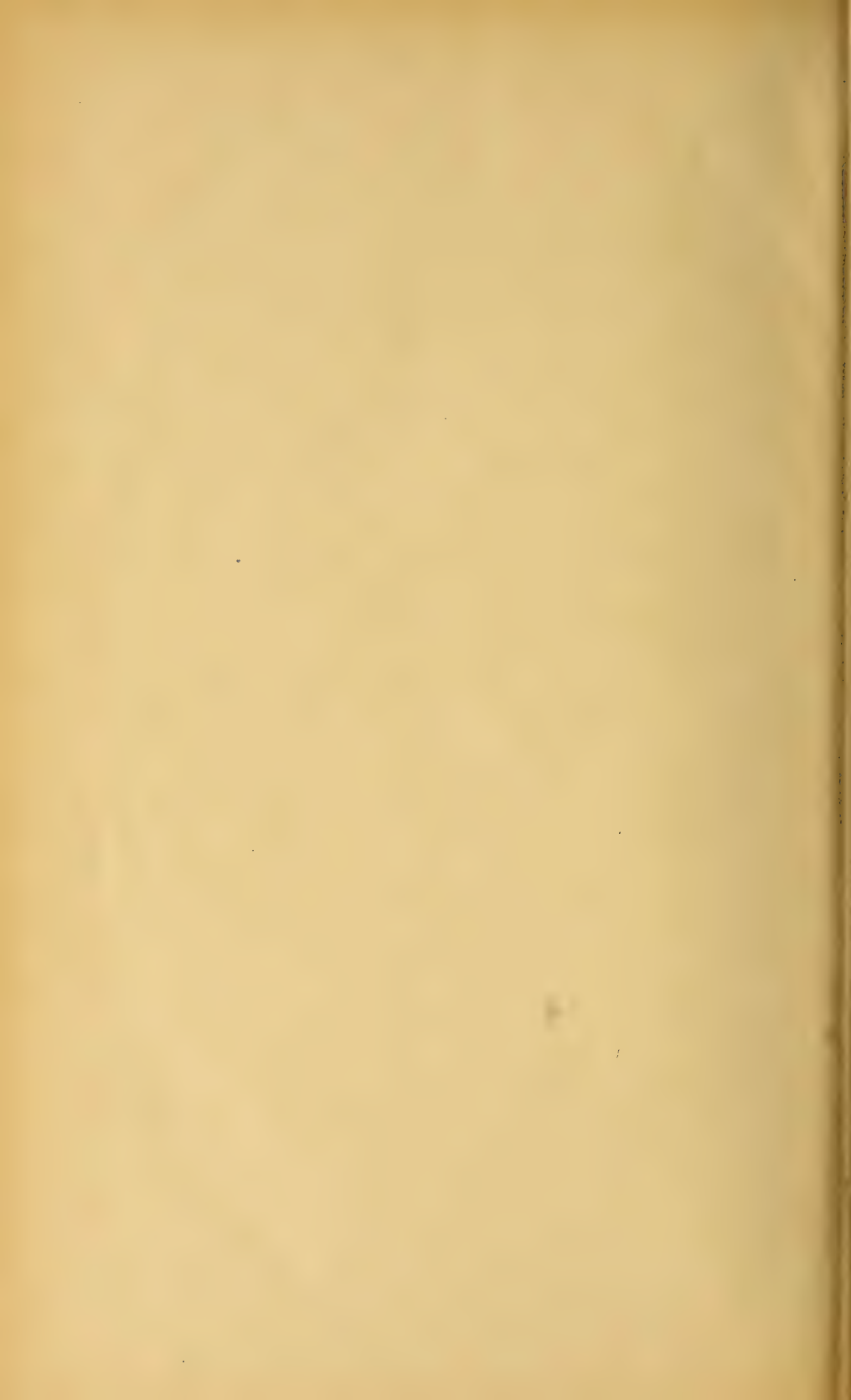
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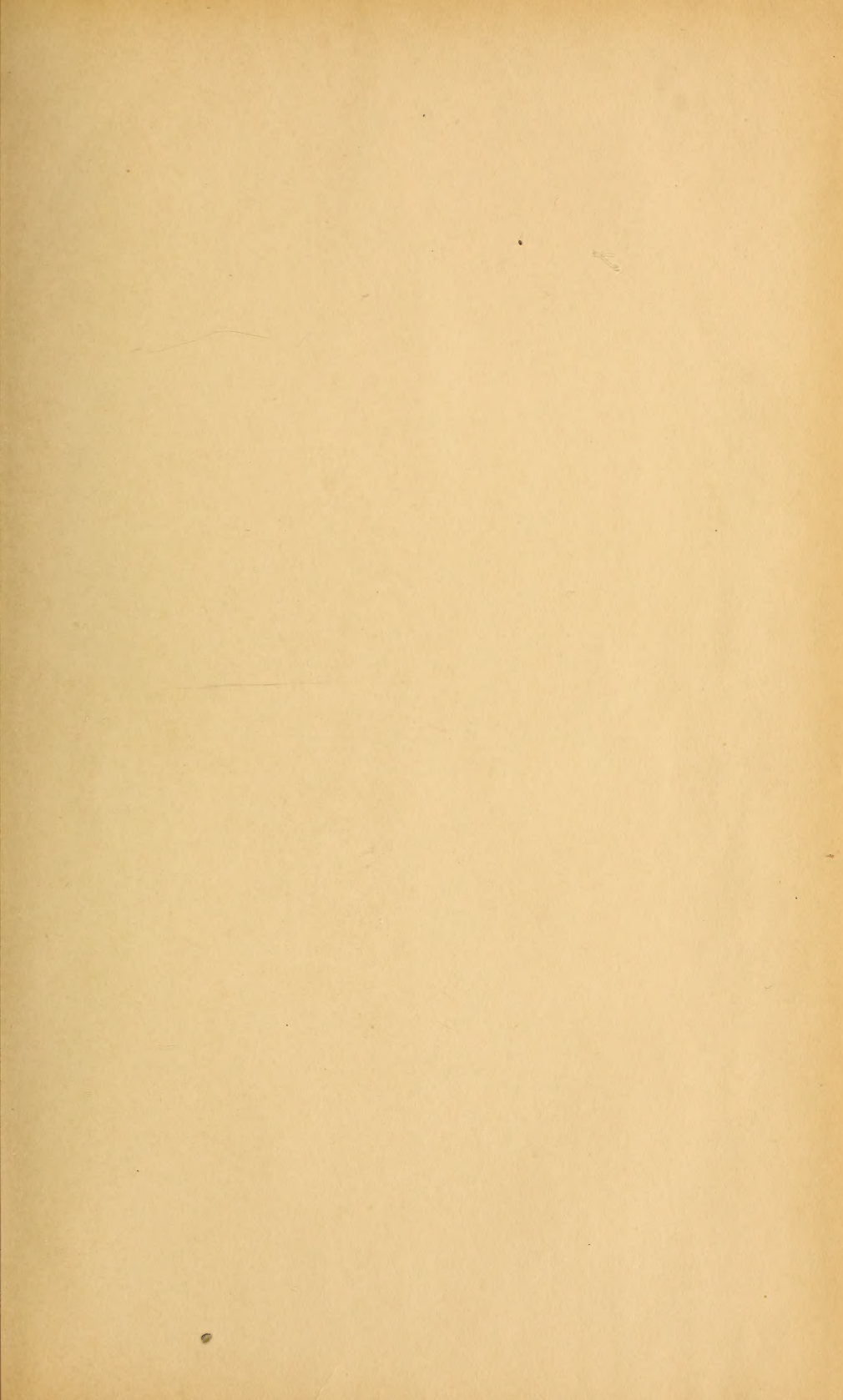
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